DOCUMENT RESUME

ED 211 818 CE 031 109

TITLE	Instrumental Drawing, Book 1.
INSTITUTION	Connecticut State Dept. of Education, Hartford. Bureau of Vocational-Technical Schools.
PUB DATE	Sep 79
NOTE	187p.; Not available in paper copy due to light print in tables and drawings.
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Architectural Drafting; Carpentry; *Drafting; Electrical Occupations; Engineering Drawing; *Learning Activities; *Learning Modules; Metric System; Orthographic Projection; Plumbing; Postsecondary Education; Secondary Education; Sheet Metal Work; *Technical Occupations; Vocational Education; Welding; Workbooks

ABSTRACT

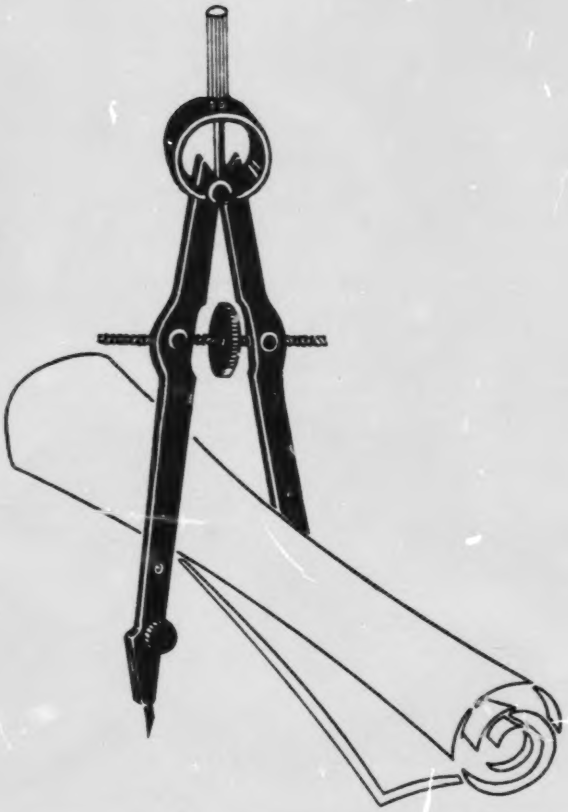
This material for student use presents the basic principles and techniques of drafting and provides experiences in the application of these skills to a wide variety of occupational areas, including carpentry, plumbing, welding, electrical, and sheet metal trades. The workbook contains 20 units, organized into seven sections. Sections cover introduction to drawing equipment and supplies, basic instrumental drawing, dimensioning and notes, orthographic projections, pictorial drawings, sectional representatives, and metric applications. The text is illustrated, and each unit contains explanatory material and student assignments. An appendix to the materials contains tables of standard measurements, standard sizes, and equivalents. (KC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED211818

INSTRUMENTAL DRAWING

BOOK 1



U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

V. Pichanick

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

CE031109

CONNECTICUT STATE DEPARTMENT
DIVISION OF VOCATIONAL TECHNICAL SCHOOLS
HARTFORD, CONNECTICUT

Preface

Instrumental Drawing

THE OBJECTIVE of this material is to present the basic principles and techniques of drafting and to provide experiences in the application of these skills to a wide variety of occupational areas. It was the thinking of the Curriculum Committee that the most feasible way to accomplish this was to provide an abundance of practical problem material with emphasis on special application of drafting in specific trade areas. Thus, the basic fundamentals are followed by a Section of specific units applying these skills to the particular requirements found in carpentry, plumbing, welding, electrical, and sheet metal trades.

The implementation of this material depends, of course, on each individual instructor. Additional problems to meet the needs of your own students should be added. The use of audio-visual aids, references and home assignments is highly recommended and encouraged. And, as members of the Curriculum Committee, each instructor is enjoined to take note of those portions of this material which prove entirely functional *and* suggest better methods to improve portions which, in classroom experience, fail to measure up to desired standards. It is only by such means that the highest quality instructional material will evolve and it shall require the constructive cooperation of all concerned to accomplish this aim.

September, 1979
Waterbury, Connecticut

Contents

SECTION I *INTRODUCTION*

Unit 1 Equipment and Supplies 1

Assignment 9

Unit 2 Use and Care of Drawing Instruments 10

Assignment 16

SECTION II *BASIC INSTRUMENTAL DRAWING*

Unit 3 Lines and Their Characteristics 17

Assignment 21

Unit 4 Preparation for Drawing 22

Assignment 24

Unit 5 Lettering 27

Assignment 32

Unit 6 Geometric Constructions 34

Assignment 50

Unit 7 Orthographic Concept 52

Assignment 58

Unit 8 Freehand Sketching 60

Assignment 66

SECTION III *DIMENSIONING AND NOTES*

Unit 9 Dimensioning and Notes 70

Assignment 73

Unit 10 Fractional and Decimal Dimensioning 74

Assignment 77

Unit 11 Surface Quality Finishes 78

Assignment 81

Contents

SECTION IV *ORTHOGRAPHIC PROJECTIONS*

Unit 12 Orthographic Drawing - Straight Surfaces 82
Assignment 82
Unit 13 Orthographic Drawing - Curved Surfaces 98
Assignment 99

SECTION V *PICTORIAL DRAWINGS*

Unit 14 Isometric Pictorial Drawings 108
Assignment 112
Unit 15 Oblique Pictorial Drawings 119
Assignment 119

SECTION VI *SECTIONAL REPRESENTATIVES*

Unit 16 Sectional Views 120
Assignment 124
Unit 17 Auxiliary Views 133
Assignment 139
Unit 18 Threads 146
Assignment 153
Unit 19 Detail Assembly 155
Assignment 156

SECTION VII *METRIC APPLICATIONS*

Unit 20 The Metric System 161

APPENDIX

SECTION I *INTRODUCTION*

Unit 1 EQUIPMENT AND SUPPLIES

The equipment needed to satisfactorily complete the required work in this book is:

Drawing board, 22″ × 26″	Pencils, H and 2H
T-square, 24″	Erasing equipment
Triangles, 30°—60° and 45°	Bow compass
Architects' scale, 12″	Dividers

DRAWING BOARD

The drawing board has a smooth flat surface on which the drawing paper is placed. It is often made of a soft wood such as white pine or bass wood. Drafting tape is the preferred method of affixing the drawing paper to the board. Thumb tacks or staples are sometimes used. The drawing board should be at least 18″ wide and 24″ long. Many are larger.

T-SQUARE

The T-square is shaped like the letter T as shown in Fig. 1-1. It has two parts called the head and the blade. The blade approximates two right angles with the head.

When you draw lines, the head of the T-square should always be held firmly against the left edge of the board with your left hand. All directions in this and the following sections are for right handed people.

The upper blade edge and inner head edge are the working edges.

Horizontal lines are drawn along the upper edge of the blade. The lines should be drawn from left to right.

This instrument is very delicate and paper should not be cut along a working edge. When not in use, it should be hung on a peg by a hole in the end of the blade.

T-squares are made from a variety of woods, plastics, laminates and steel.

The majority of T-squares have fixed heads. Some, however, have dual heads which may be used either as a regular T-square or as an angle preset on an adjustable head.

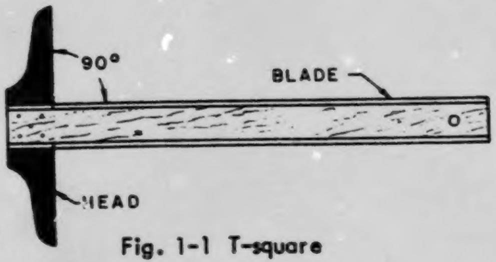


Fig. 1-1 T-square

STRAIGHTEDGE

A straightedge is similar to the edge of a T-square with the head removed. The length of the straightedge conforms to the length of the drawing board. Attachments at each edge of the drawing board (a pulley and track arrangement) and at each end of the straightedge are engaged so that an up and down movement is possible.

TRIANGLES

Two right angle triangles are regularly used by the draftsman. One has angles of 90°, 60°, and 30°. The other has one angle of 90° and two angles of 45°.

Another type commonly used is the adjustable triangle, Fig. 1-2. The construction of this triangle incorporates the principle of the protractor as illustrated in Fig. 1-11.

Triangles are used for drawing both vertical and sloping lines. When used with a T-square, they are held against the upper edge of the blade with the vertical edge to the left. This assures that the lines drawn will be parallel. Alternating the vertical edge from the left to the right may result in unparallel lines because of the error in the construction of the triangle. This is illustrated by Fig. 1-3.

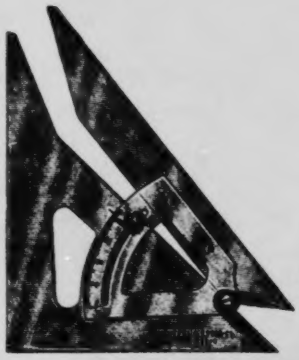


Fig. 1-2 Adjustable triangle

With the T-square and the 30°-60° triangle, angles of 30°, 60°, 90°, 120° and 150° can be drawn as shown in Fig. 1-4.

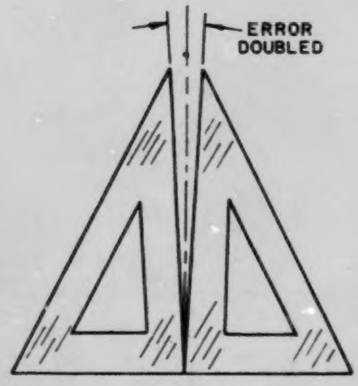


Fig. 1-3 Reason for positioning the vertical edge of the triangle consistently to the left

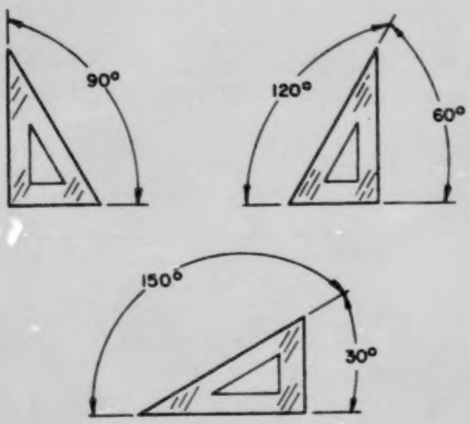


Fig. 1-4 Angles drawn with a 30° - 60° triangle

With the T-square and the 45° triangle, angles of 45°, 90° and 135° can be drawn, as shown in Fig. 1-5.

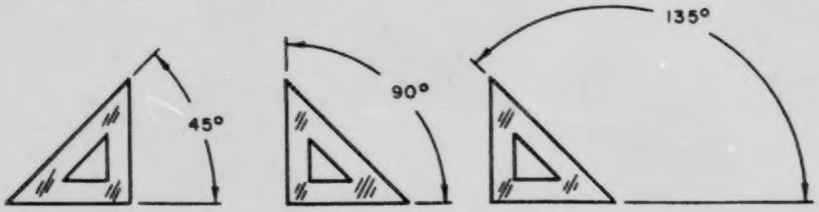


Fig. 1-5 Angles drawn with a 45° triangle

Using both triangles in combination, angles of 15°, 75°, 105° and 165° can be drawn, as shown in Fig. 1-6. Other combinations of faces give only these four angles.

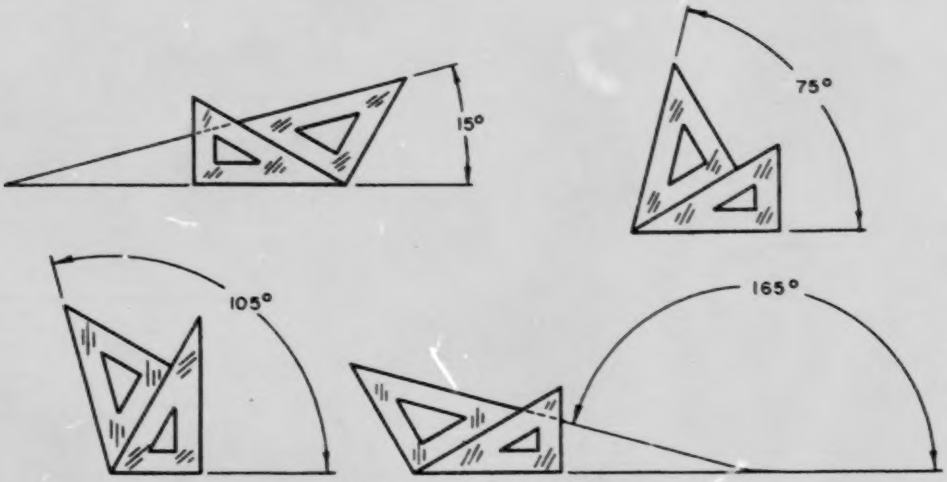


Fig. 1-6 Angles drawn with combined triangles

SCALES

Scales are used for measuring. The three general types are:

- ✓ Architects' scales
- ✓ Engineers' scales
- ✓ Metric scales

Fig. 1-7 Architects' scale

The architects' triangular scale has six faces. One face is divided into twelve one-inch divisions; each inch is divided into sixteen equal parts, or sixteenths of an inch. The other five faces have reduced or enlarged scale sizes which may be used. The division of these scales is in twelfths, twenty-fourths, etc. For example, 1/12 on the scale could be used for a reduced scale size to equal 1" and 12/12 would equal 1'.

Flat scales are used by professional draftsmen because their shape makes them easy to handle.

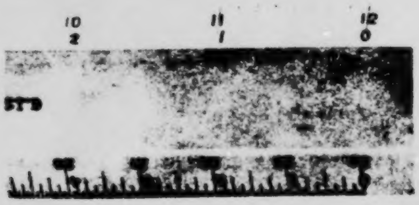


Fig. 1-8 Mechanical engineers' flat scale

Mechanical engineers' scales, Fig. 1-8, are used for drawings of machines and machine parts. The scales are either full size or half size as a rule. However, one quarter and one eighth scales are used occasionally. On a full size scale, one inch equals one inch; on a half size scale, one half inch equals one inch.

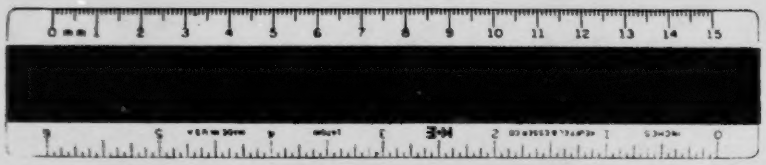


Fig. 1-9 Metric scales

Metric scales are divided into centimeters, millimeters and half millimeters for full size drawing.

A full-divided scale is one in which the basic units are subdivided throughout the entire length of the scale, and is used when a series of measurements is made from a given point. In an open-divided scale the end unit only is subdivided. The open type is illustrated in Fig. 1-7.

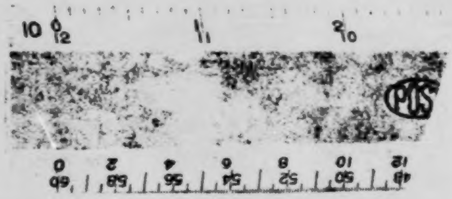


Fig. 1-10 Civil engineers' flat scale

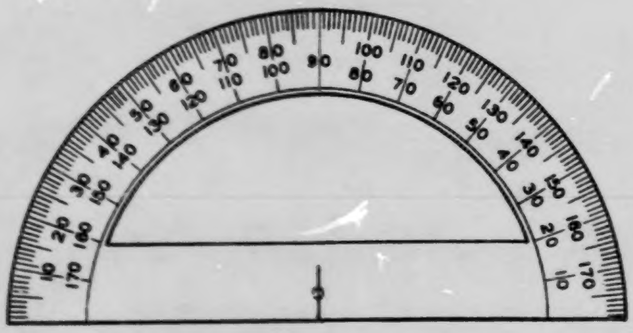


Fig. 1-11 Protractor

Scales are usually made of boxwood; the better types have celluloid edges.

The protractor, Fig. 1-11, is used for laying out angles which cannot easily be drawn with the T-square and triangles. Present day draftsmen prefer to use the adjustable triangle shown in Fig. 1-2.

PENCILS

Pencils used for drawing are graded according to the degree of hardness of the lead.

The lead is made chiefly of graphite, mixed with varying quantities of clay, to produce 18 degrees of hardness. See Fig. 1-12.

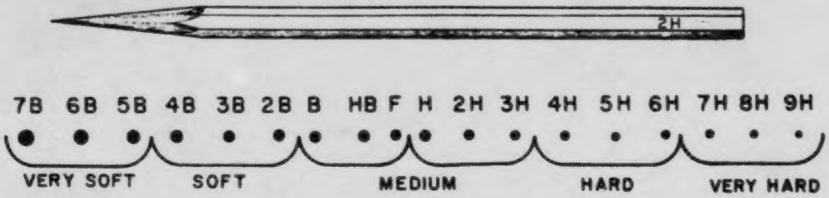


Fig. 1-12 Scale of pencil hardness

The degree of hardness of the lead may be judged roughly by its diameter; the smaller the diameter, the harder the lead.

CURVES AND TEMPLATES

Irregular and adjustable curves are guides for connecting points plotted for curves other than a circle or circle arc. See Figs. 1-13 and 1-14.

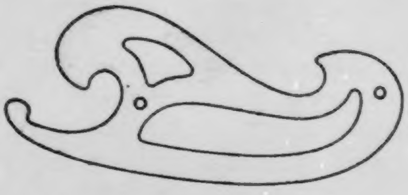


Fig. 1-13 Irregular curve (French)

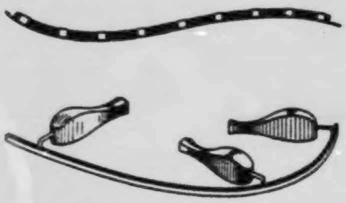


Fig. 1-14 Adjustable curves

Draftsmen are turning to drafting aids such as templates and lettering devices to simplify the job and to minimize time-consuming operations. See Figs. 1-15 and 1-16.

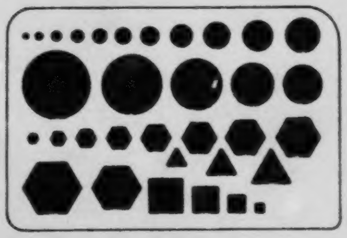


Fig. 1-15 Template

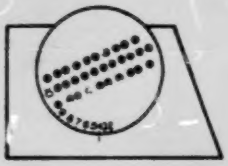


Fig. 1-16 Lettering aid

ERASERS AND THEIR ACCESSORIES

Erasers are available in different degrees of abrasiveness.

A soft pencil eraser with a beveled edge is used for erasing lines. An artgum eraser may be used for final cleaning of a drawing, see Figs. 1-17 and 1-18.

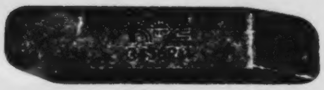


Fig. 1-17 Pencil eraser

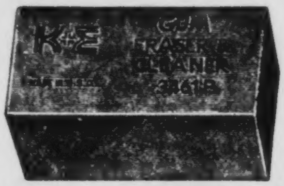


Fig. 1-18 Artgum eraser

Commercial grit erasers and ink erasers are to be avoided because their abrasive action harms the surface of the paper. Pencil erasers are satisfactory for ink lines if enough pressure is applied.

A knife eraser, Fig.1-19, or an Exacto Blade, is sometimes used to remove tiny portions or segments of ink lines. These are not recommended for general use.

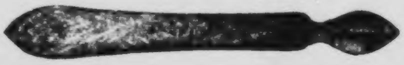


Fig. 1-19 Knife eraser

The electric erasing machine, Fig. 1-20, is efficient but must be used with care or the eraser will go through the paper because of its high speed of rotation.

Erasing shields are thin metal plates with various shaped openings in them. When used, the shield is placed on the drawing so that the line to be erased appears in one of the openings. As the line is erased, the shield protects other lines near it.

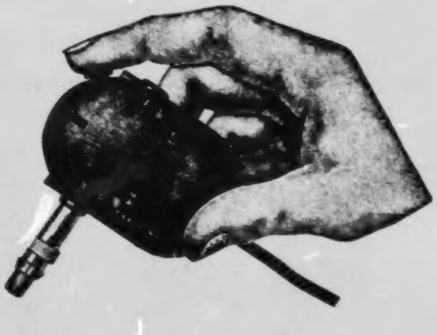


Fig. 1-20 Electric erasing machine

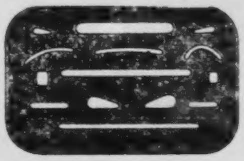


Fig. 1-21 Erasing shield

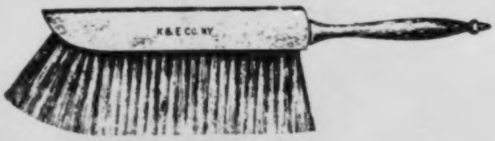


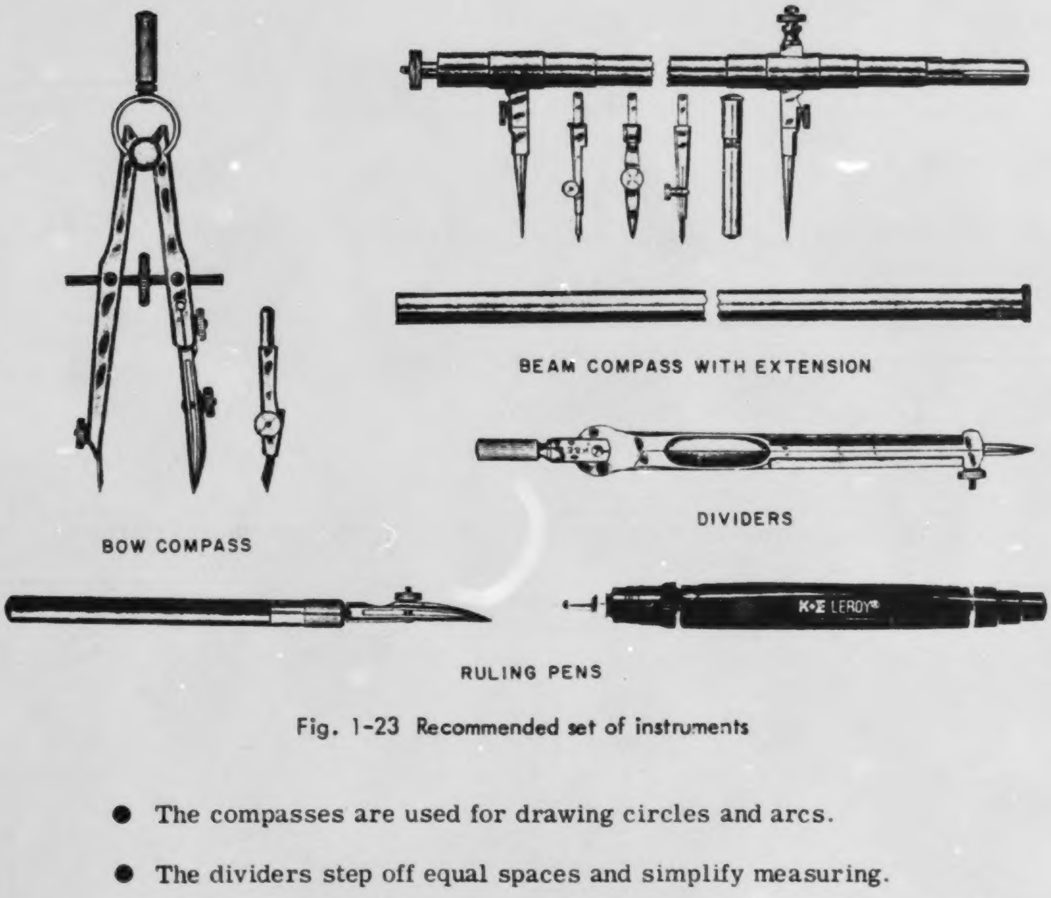
Fig. 1-22 Dusting brush

A dusting brush made of nylon or horsehair is helpful in removing erasings from the board, drawing or table. Horsehair bristles, being softer, are preferred.

DRAWING INSTRUMENTS

Instruments are available to aid in drawing. Sets of these instruments contain at least one of each of the following:

✓ 6″ bow compass, pencil with ink attachment
✓ 3″ bow compass, pencil with ink attachment
✓ 6″ divider
✓ Ruling pen
✓ Beam compass with extension



BEAM COMPASS WITH EXTENSION

DIVIDERS

BOW COMPASS

RULING PENS

Fig. 1-23 Recommended set of instruments

- The compasses are used for drawing circles and arcs.
- The dividers step off equal spaces and simplify measuring.
- The ruling pen inks straight lines and in some instances curved lines.

Various types of noncorrosive steel (stainless, spring, nickel, etc.) are used for ruling pens, spring parts, divider points and various screws.

SUPPLIES

The supplies needed to satisfactorily complete the required work in this manual are:

Drawing Paper
Adhesive Drafting Tape

DRAWING PAPERS

The paper to be used depends entirely upon the type of drawing, its purpose and its use.

In general practice all pencil drawings were formerly made on white or pastel paper. Then the drawings were traced by placing tracing paper or tracing cloth over the drawing and tracing it in ink or pencil. Today it is customary to make pencil drawings directly on the tracing paper or tracing cloth. Ozalids, blueprints and other reproduced forms are then made directly from the drawing which is, in effect, a tracing.

The standard untrimmed sizes of paper are 9 × 12, 12 × 18, 18 × 24, and 24 × 36.

The American Standard Association trimmed sizes of drawing paper and cloth are as follows.

A - 8 1/2 × 11
B - 11 × 17
C - 17 × 22
D - 22 × 34
E - 34 × 44
Others - multiples of 34 × 55 etc.

Tracing paper is a thin transparent paper upon which tracings of drawings are made. Two kinds of tracing paper are available:

- Those treated with oils or waxes to render them more transparent.
- Those not treated but already transparent, due to the high quality of material used and methods of manufacture.

Tracing cloth is a thin, transparent fabric (linen) which has been "sized" (treated) with a starch compound to provide a good working surface.

Most large corporations now use a plastic material called polyester film which has a matte (dull) finish on the drawing side. This material is suitable for pencil or ink drawings and is preferable to drawing cloth because of its durability and tendency to remain flat. With this material a special type pencil should be used. If a common drawing pencil is used the drawing tends to smudge. Erasing is much safer and neater because of the material's thickness.

ADHESIVE DRAFTING TAPE

For many years thumb tacks were used to affix the drawing paper to the board. The present practice is to use good quality adhesive drafting tape. A 1″ length of 3/4″ tape is used at a 45° angle across the four corners of the paper to hold it to the board. Tape is preferred to tacks or staples since it does less damage to the board.

ASSIGNMENT

1. List the drawing equipment necessary to complete the problems contained in this book.
2. Describe the features of the drawing board.
3. What is the function of a T-square?
4. What angles can be drawn with a 30° triangle; a 45° triangle?
5. Using a 30° and a 45° triangle, what combinations of angles can be drawn?
6. What are the three general types of scales and their respective graduations?
7. List the degrees of lead hardness of pencils in the medium and hard range.
8. What are the functions of the irregular and adjustable curves?
9. List some drafting aids used today by the draftsman.
10. List the various types of erasers the draftsman uses and their application.
11. List and describe the various instruments in a basic drawing set.
12. List the A.S.A. trimmed and untrimmed paper sizes.
13. Describe the uses of the following:

    drawing paper
    tracing paper
    polyester film
    adhesive tape

Unit 2 USE AND CARE OF DRAWING INSTRUMENTS

At first, you will make sketches freehand and without the use of a scale. As work progresses, all sketches will be made to a definite scale.

Let us suppose that an object is so large that only half of it can be drawn on a sheet of drawing paper. Therefore, it is plain, that in order to draw the whole object, we must double the size of the paper or make the drawing of the object half the actual size of the object. In drawing the object one-half size we assume that the dimensions are only half of those given. In other words, if the object were one foot long we would make the sketch or drawing 6 inches, even though we would show the dimension as 12 inches on the completed sketch. Other distances would be proportional, see Fig. 2-1.

5 1/2" distance on the object would equal 2 3/4" distance on the sketch.
3 3/4" distance on the object would equal 1 7/8" distance on the sketch.
1" distance on the object would equal 1/2" distance on the sketch.

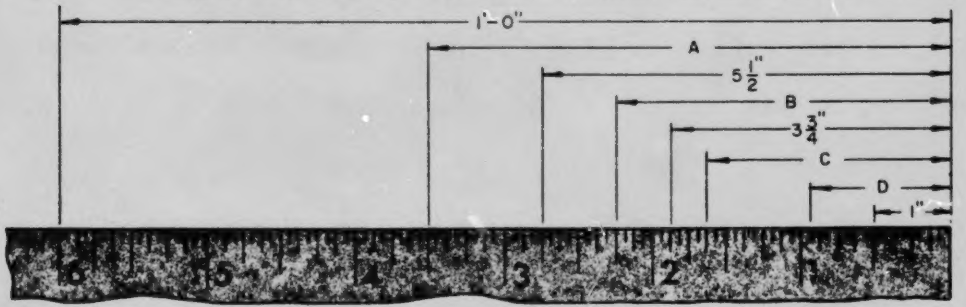


Fig. 2-1 Reading scale: 6"=1'-0"

Refer to the 1/4 size scale, which is 3"=1'-0", Fig. 2-2. In this case, 3" on the sketch is equivalent to 12" on the object, and other distances would be proportional.

2'-0" distance on the object would equal 6" on the sketch.
11" distance on the object would equal 2 3/4" on the sketch.
8 3/4" distance on the object would equal 2 3/16" on the sketch.
2 1/4" distance on the object would equal 9/16" on the sketch.

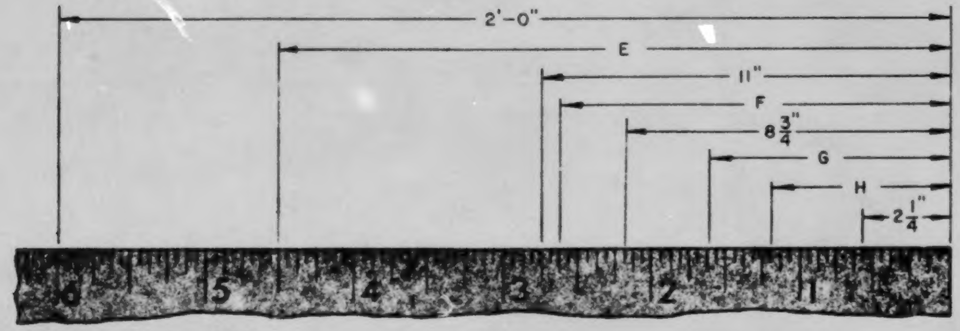


Fig. 2-2 Reading scale: 3"=1'-0"

The most commonly used scale is the 1/4"=1'-0" or 1/48 actual size scale. This scale is illustrated in Fig. 2-3.

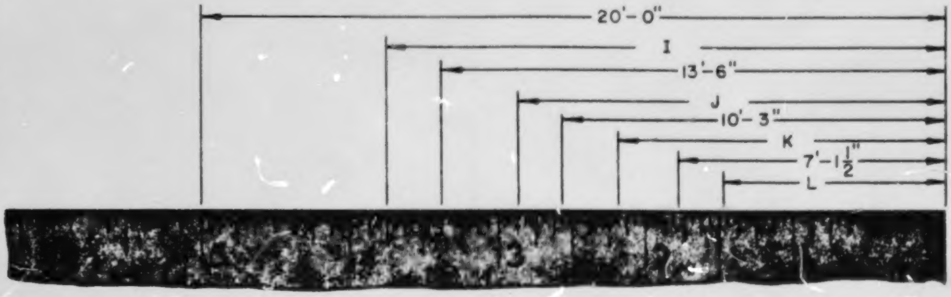


Fig. 2-3 Reading scale: 1/4" 1'-0"

Occasionally you will find objects that are so large that it is necessary to draw them to the scale of 1/8"=1'-0". See Fig. 2-4.

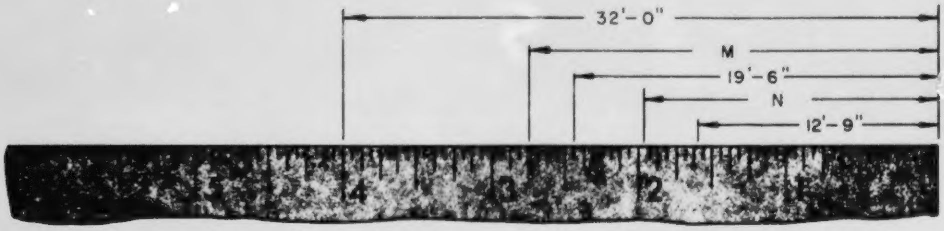


Fig. 2-4 Reading scale: 1/8" 1'-0"

Some objects that you will be called upon to sketch are so small that it is impractical to sketch them to their full size. The scale 24"=1'-0" (2-1 ratio) makes it possible to sketch the object two times its actual size. This scale is shown in Fig. 2-5.

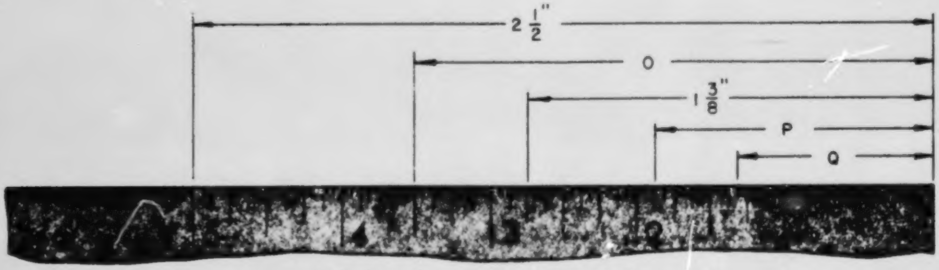


Fig. 2-5 Reading scale: 24" 1'-0" or 2-1

Problem 1. Now that you have studied separately each scale in Figs. 2-1 through 2-5, go back and give dimensions that are marked in alphabetical order in each figure.

Below you will find additional illustrations in the use of the scale as applied to an object.

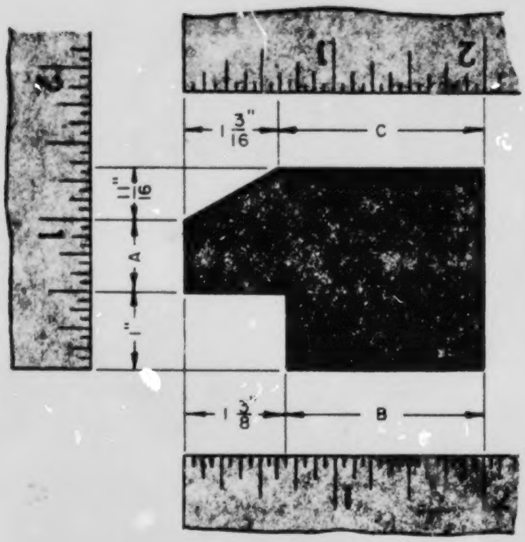

1 3/16"
C
11/16"
A
1"
1 3/8"
B
1
2

Fig. 2-6

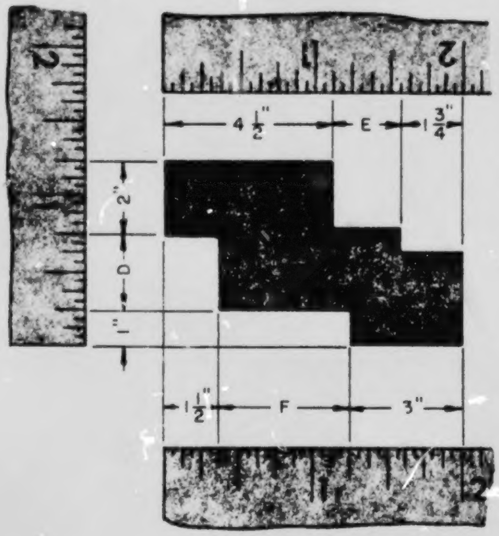

4 1/2"
E
1 3/4"
2"
D
1"
1 1/2"
F
3"
1
2

Fig. 2-7

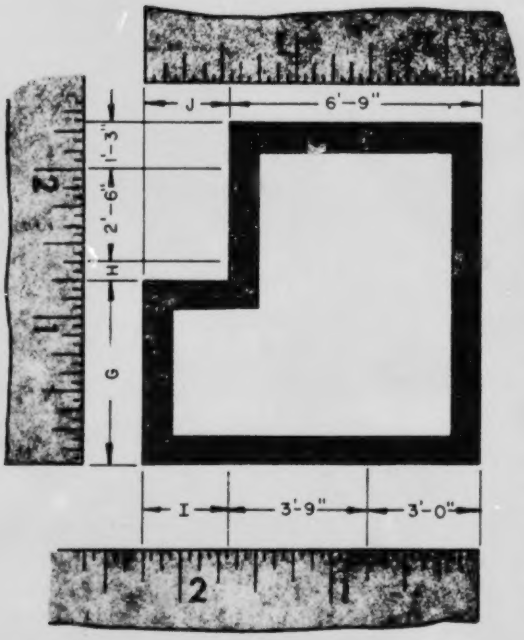

J
6'-9"
1'-3"
2'-6"
H
G
I
3'-9"
3'-0"
2
1

Fig. 2-8

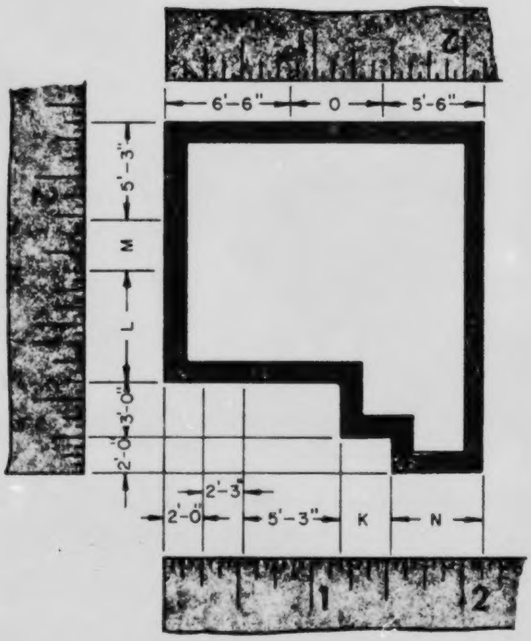

6'-6"
O
5'-6"
5'-3"
M
L
3'-0"
2'-0"
2'-3"
2'-0"
5'-3"
K
N
1
2

Fig. 2-9

Problem 2. In the above figures find the distance of each dimension that is listed in alphabetical order in each figure.

In the previous two paragraphs we have demonstrated the use of a conventional ruler in conjunction with blueprint reading. Figs. 2-10 and 2-11 show the two faces of an architect's scale, each face having four scales. By using these scales a large object may be reduced in proportion. The following paragraphs will explain the scale that the architectural draftsman uses.

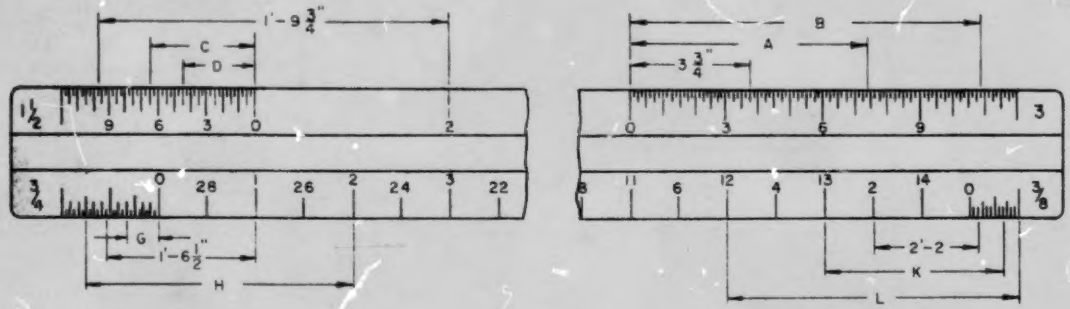

1'-9 3/4"
C
D
1 1/2
9
6
3
0
2
3/4
0
28
1
26
2
24
3
22
G
1'-6 1/2"
H
B
A
3 3/4"
0
3
6
9
3
8
11
6
12
4
13
2
14
0
3/8
2'-2
K
L

Fig. 2-10

Refer to Fig. 2-10 upper left edge. This scale is graduated 1 1/2"=1'-0" or 1/8th of the actual full size.

Upper right edge. This scale is graduated 3"=1'-0" or 1/4th actual full size.

Lower left edge. This scale is graduated 3/4"=1'-0" or 1/16th of actual full size. This scale may also be used as 3/4"=1", 9"=1'-0" or 3/4 of full size.

Lower right edge. This scale is graduated 3/8"=1'-0" or 1/32nd of full size. This scale may also be used as 3/8"=1" or 3/8ths of full size.

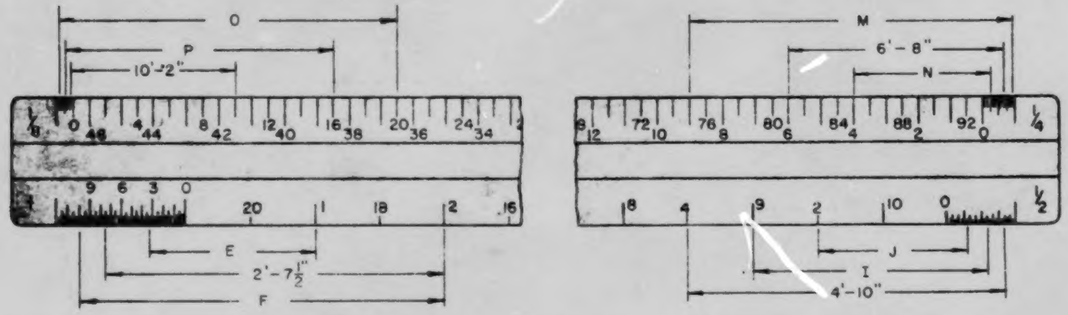

O
P
10'-2"
1/8
0
48
4
44
8
42
12
40
16
38
20
36
24
34
9
6
3
0
20
1
18
2
16
E
2'-7 1/2"
F
M
6'-8"
N
8
12
72
10
76
8
80
6
84
4
88
2
92
0
1/4
8
4
9
2
10
0
1/2
J
I
4'-10"

Fig. 2-11

Refer to Fig. 2-11 upper left edge. This scale is graduated 1/8"=1'-0" or 1/96th of full size. This scale may also be used as 1/8"=1" or 1/8th of the actual full size.

Upper right edge. This scale is graduated 1/4"=1'-0" or 1/48th of full size. This scale may also be used as 1/4"=1" or 1/4th of the actual full size.

Lower left edge. This scale is graduated 1"=1'-0" or 1/12th of full size.

Lower right edge. This scale is graduated 1/2"=1'-0" or 1/24th of full size. This scale may also be used as 1/2"=1", 6"=1'-0" or 1/2 of full size.

Problem 3. You will notice a dimension on each of the scales above. These figures give you the correct scale reading. To assure your instructor that you can read the dimensions correctly give the answers by lettering neatly the dimensions designated by letters in alphabetical order.

USE AND CARE OF A PENCIL

When sharpening a pencil the wood should be cut away leaving about 3/8" of lead exposed. The lead is then sharpened by rubbing it on a file or sandpaper pad.

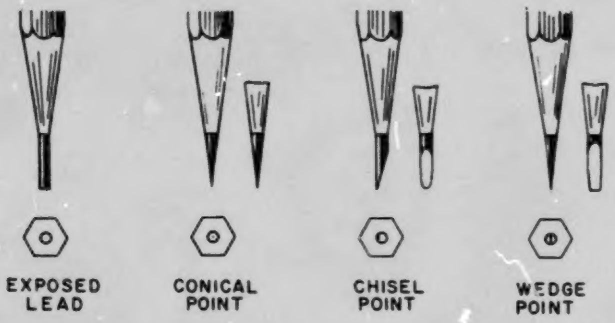

EXPOSED LEAD
CONICAL POINT
CHISEL POINT
WEDGE POINT

Fig. 2-12 Types of pencil points

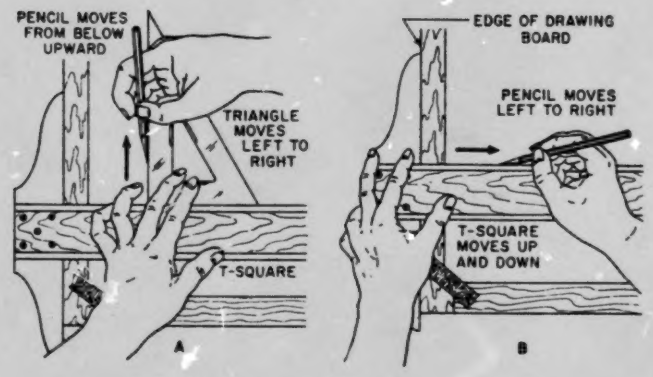

PENCIL MOVES FROM BELOW UPWARD
TRIANGLE MOVES LEFT TO RIGHT
T-SQUARE
A
EDGE OF DRAWING BOARD
PENCIL MOVES LEFT TO RIGHT
T-SQUARE MOVES UP AND DOWN
B

Fig. 2-13

A conical-shaped point is preferred for lettering and measuring. When used for drawing lines it is rotated as the line is drawn so that the point wears evenly and an even weight line is produced. See Fig. 2-13.

A wedge-shaped point is sometimes preferred for drawing lines. Its advantage is that various weight lines can be obtained by changing the position of the wedge.

Chisel-shaped points are most often used with pencil compasses.

A conical point is formed by rotating the lead on the file or pad while exerting some pressure, producing a cone-shaped end.

The wedge point is formed by rubbing two opposite sides of the lead on the sandpaper pad or file, shaping the point similar to the end of a screwdriver.

A chisel point is made by rubbing one side of the lead on the sandpaper pad, forming a point like the working edge of a chisel.

USE OF A COMPASS

The compass is used for drawing circles and circular arcs. The lead should be several grades softer than the pencil. The compass lead is sharpened as shown in Fig. 2-14 and the pencil leg should be approximately 1/64 shorter than the point. To draw a circle, locate the needle point at the intersecting lines and swing the compass in a clockwise direction inclined about 75° in the direction of motion. Fig. 2-15

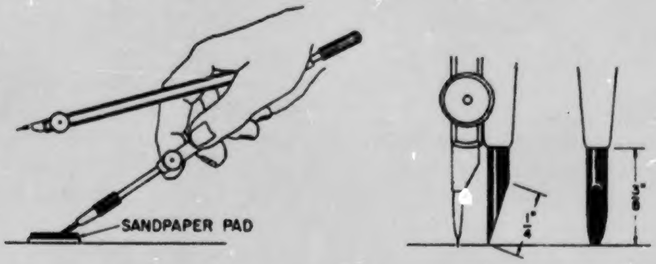


Fig. 2-14

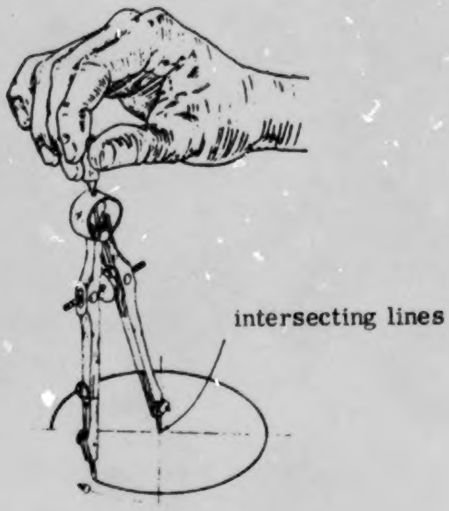


Fig. 2-15

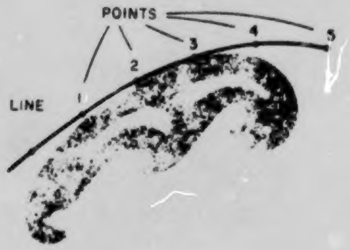
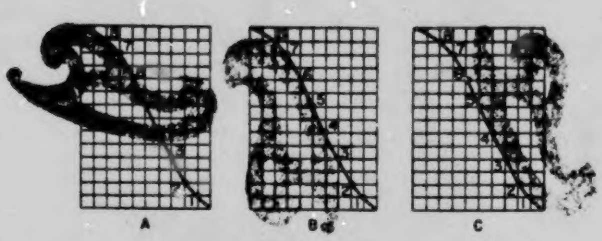


Fig. 2-16

USE OF THE IRREGULAR AND ADJUSTABLE CURVES

The irregular, or French, and the adjustable curves are used to draw a smooth curve through a series of points. The curve serves as a guide for connecting points plotted for curves other than circles or circular arcs. When placing the curve on a set of points a minimum of 3 points if possible should be used, as shown in Fig. 2-16 It is advisable to draw a smooth freehand curve through the located points and then to select a part of the irregular curve that lines up with as many adjacent points as possible, as shown in Fig. 2-17. The portion of the curve selected should always line up with two adjacent points and extend toward the next adjacent point. It is important to stop drawing the curve before reaching the last point at which the irregular curve matches the freehand curve, as shown at (A). Then, when the irregular curve is

Fig. 2-17



placed in the second position (B), it should line up with a portion of the curve already drawn and with as many new points as the curve may be made to coincide with. Similarly, the next position of the irregular curve is shown at (C). In this way, a series of short curves may be made to flow into a smooth and continuous irregular curve indicated by the points.

ASSIGNMENT

1. Match the following:

    (1) 1/96 size
    (2) 1/2 size
    (3) 1/48 size
    (4) 2/1 size
    (5) 1/4 size

    a. 1/4" = 1'-0"
    b. 24" = 1'-0"
    c. 1/8" = 1'-0"
    d. 6" = 1'-0"
    e. 3" = 1'-0"

2. How much lead should be left exposed after cutting away the wood from a pencil?

3. Name three types of pencil points and explain their use.

4. In what direction should the pencil travel when drawing vertical lines? When drawing horizontal lines?

5. What type of lines can be obtained through the use of a compass?

6. Approximately how much should the lead protrude from the end of the lead housing?

7. What should the correct relationship be between the end of the sharpened compass lead and the end of the needle point?

8. What is the main purpose for using the irregular or adjustable curve?

9. What is understood to be the minimum number of points in a series that should be used as a guide when plotting a curve?

10. What method is used to connect the established points before applying the irregular curve?

SECTION II *BASIC INSTRUMENTAL DRAWING*

Unit 3 LINES AND THEIR CHARACTERISTICS

One of the most important essentials to a drawing is the line work. The lines represent the general shape or contour of an object. Three different thicknesses of lines, as recommended by the A.S.A., are used. Thick lines are used for visible outlines, cutting plane and short-break lines, medium lines are used for hidden outlines, and thin lines are used for section, center, extension, dimension and long-break lines. The professional appearance of a drawing depends mostly on the line weights used.

In preparing for a drawing, the table should be adjusted to a convenient height and should be slightly slanted. Lighting should come from the left. The instruments should be placed within easy reach and, along with the table, should be cleaned or wiped before starting to draw.

Another important essential to a drawing is the lettering. As far as appearance is concerned, lettering determines the neatness of the drawing. The description figured dimensions, material and finish notes, and descriptive title, added to representation of the shape of the object, gives full information for construction of the object. When lettering a drawing, guide lines should always be used.

A draftsman should have a thorough knowledge of geometry and its constructions. Geometry and applications of its principles will help solve many drawing problems. Other instruments besides T-squares, triangles, scales and curves are used to make constructions quickly and accurately. Principles must be mastered thoroughly.

Orthographic projection is the representation of the exact shape of an object by dropping perpendiculars from two or more sides of the object to planes, usually at right angles to each other. The views on these planes completely describe the object. The shape is described by projection, or forming an image by rays of sight taken in a certain direction from an object to a picture plane.

When designing an object, an idea may come into the mind in the form of a picture. To preserve this idea, a pictorial or freehand sketch must be made. From this sketch, an orthographic drawing can later be made. A freehand sketch can be used to explain or clarify a working drawing which is hard to understand. The engineer or draftsman should be trained in this area because it will be very useful to him.

In an orthographic drawing, an intersection will occur. There may be lines of intersection between different surfaces, such as between two planes or a cylinder and a plane. These intersections will give certain shapes to a drawing such as a circle, ellipse, or straight line. An intersection of surfaces refers to lines occurring when two or more geometric shapes intersect each other, such as cones, planes, or cylinders. When working with sheet metal, these intersections have to be found before the object can be developed. The development of an object is unfolding the surface and making it into a plane. This is used mostly in sheet metal work where a piece of metal must be cut to a certain size and then folded or rolled into a certain shape.

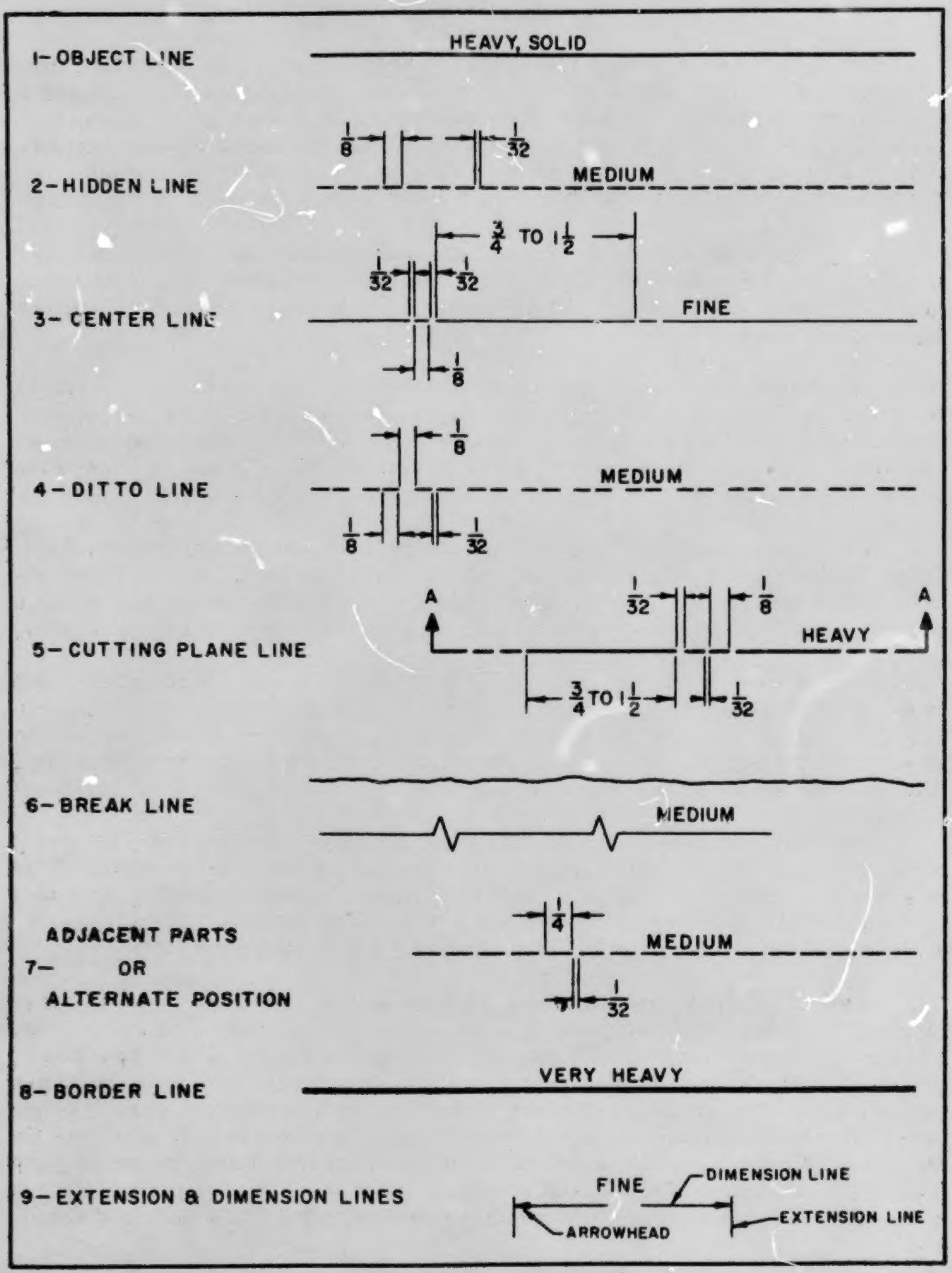

1-OBJECT LINE
HEAVY, SOLID
2-HIDDEN LINE
1/8
1/32
MEDIUM
3-CENTER LINE
3/4 TO 1 1/2
1/32
1/32
1/8
FINE
4-DITTO LINE
1/8
MEDIUM
1/8
1/32
5-CUTTING PLANE LINE
A
1/32
1/8
A
HEAVY
3/4 TO 1 1/2
1/32
6-BREAK LINE
MEDIUM
ADJACENT PARTS
7- OR
ALTERNATE POSITION
1/4
MEDIUM
1/32
8-BORDER LINE
VERY HEAVY
9-EXTENSION & DIMENSION LINES
FINE
DIMENSION LINE
EXTENSION LINE
ARROWHEAD

Fig. 3-1 Types of lines

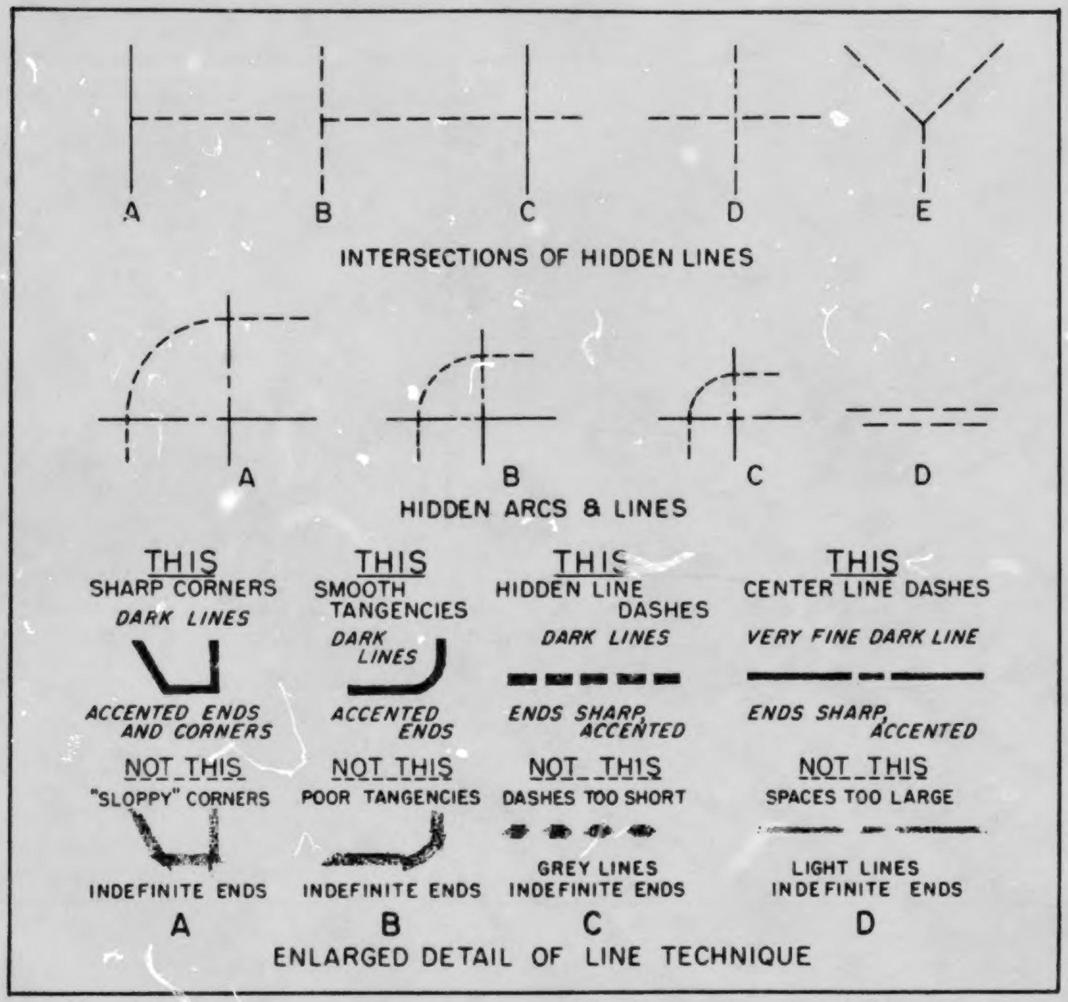

A
B
C
D
E
INTERSECTIONS OF HIDDEN LINES
A
B
C
D
HIDDEN ARCS & LINES
THIS
SHARP CORNERS
DARK LINES
ACCENTED ENDS AND CORNERS
THIS
SMOOTH TANGENCIES
DARK LINES
ACCENTED ENDS
THIS
HIDDEN LINE DASHES
DARK LINES
ENDS SHARP, ACCENTED
THIS
CENTER LINE DASHES
VERY FINE DARK LINE
ENDS SHARP, ACCENTED
NOT THIS
"SLOPPY" CORNERS
INDEFINITE ENDS
NOT THIS
POOR TANGENCIES
INDEFINITE ENDS
NOT THIS
DASHES TOO SHORT
GREY LINES
INDEFINITE ENDS
NOT THIS
SPACES TOO LARGE
LIGHT LINES
INDEFINITE ENDS
A
B
C
D
ENLARGED DETAIL OF LINE TECHNIQUE

Fig. 3-2 Correct line practices

LINE CHARACTERISTICS

The line characteristics described below apply to all drawings other than diagrams, such as schematics. (See Figs. 3-1 and 3-3)

Centerlines are composed of long and short dashes, alternately and evenly spaced with a long dash at each end, and cross without voids. Very short centerlines may be broken if there is no confusion with other lines. Centerlines also are used to indicate the travel of a center.

Dimension lines terminate in arrowheads at each end. They will be unbroken on construction drawings and will be broken on production drawings only when space is required for the dimension.

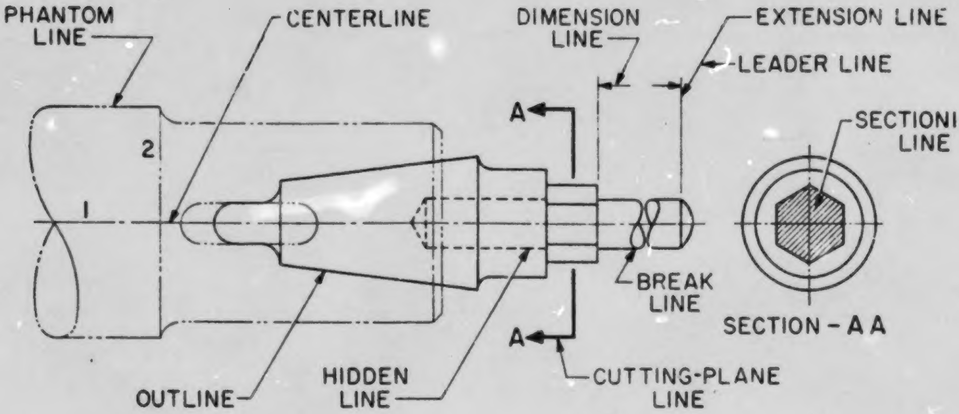


Fig. 3-3 Line connections

Leader lines are used to indicate a part or portion to which a number, note, or other reference applies and terminate in an arrowhead at the end touching the outline of the part or point of reference. Leaders should terminate at the lettering end with a line approximately one eighth inch long parallel to the lettering of the note and centered on the first line of the note.

Break lines Short breaks are indicated by solid, freehand lines. For long breaks, full, ruled lines with freehand zigzags are used.

Phantom lines are used to indicate the alternate position of delineated parts of the item, repeated detail, or the relative position of an absent part and are composed of alternating 1 long and 2 short dashes evenly spaced with a long dash at ends.

Sectioning lines are used to indicate the exposed surfaces of an object in a sectional view. They are generally full, thin lines but may vary with the kind of material shown in section.

Extension lines are used to indicate the extent of a dimension and will not touch the outline.

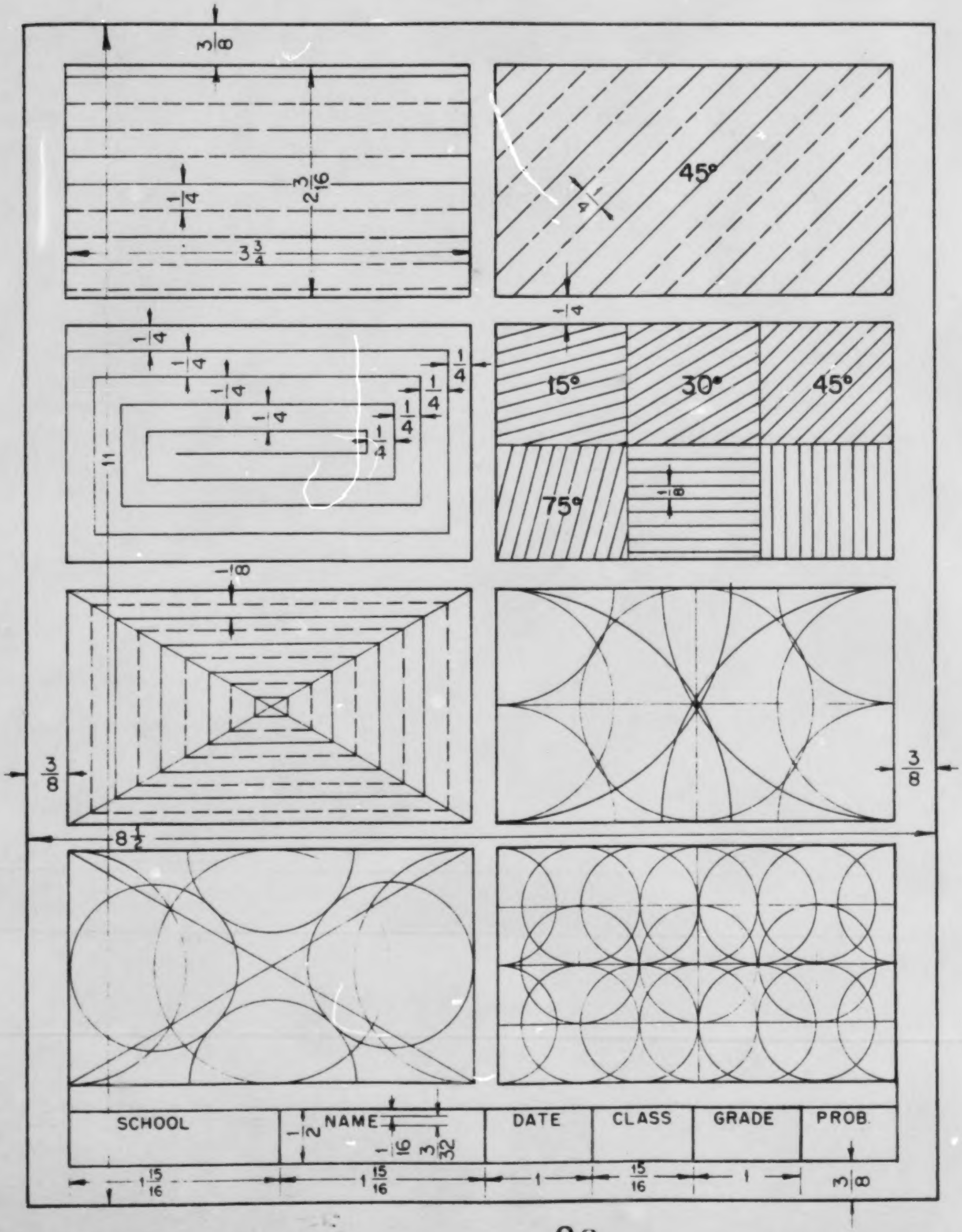
Hidden lines consist of short dashes evenly spaced and are used to show the hidden features of a part. They always begin with a dash in contact with the line from which they start, except when such a dash would form the continuation of a full line. Dashes touch at corners and arcs start with dashes at the tangent points.

Outline or visible lines are used for all lines in the drawing representing visible lines on the object.

Cutting plane lines are used to indicate a plane or planes in which a section is taken and viewing plane lines are used to indicate the plane or planes from which a surface or surfaces are viewed.

ASSIGNMENT

Redraw the following for practice in the use of lines.


3/8
2 3/16
1/4
3 3/4
45°
1/4
1/4
1/4
1/4
1/4
1/4
1/4
1/4
1/4
15°
30°
45°
75°
1/8
11
1/8
3/8
3/8
8 1/2
SCHOOL
NAME
DATE
CLASS
GRADE
PROB.
1/2
1/16
3/32
1 15/16
1 15/16
1
15/16
1
3/8

Unit 4 PREPARATION FOR DRAWING

The equipment and supplies to be used are selected, checked and then placed in an orderly manner on the drawing table before drawing is begun.

Each article should be placed so that it may be used with the greatest convenience and should be kept in that place when not in use.

In general, the position of equipment as shown in Fig. 4-1 is recommended for a right handed person (the reverse for a left handed one).

- Area A is for pencils, triangles, scales and other equipment used frequently.
- Area B is for equipment used less often.

The left side is kept free of obstructions so that the T-square head is free to move unimpeded.

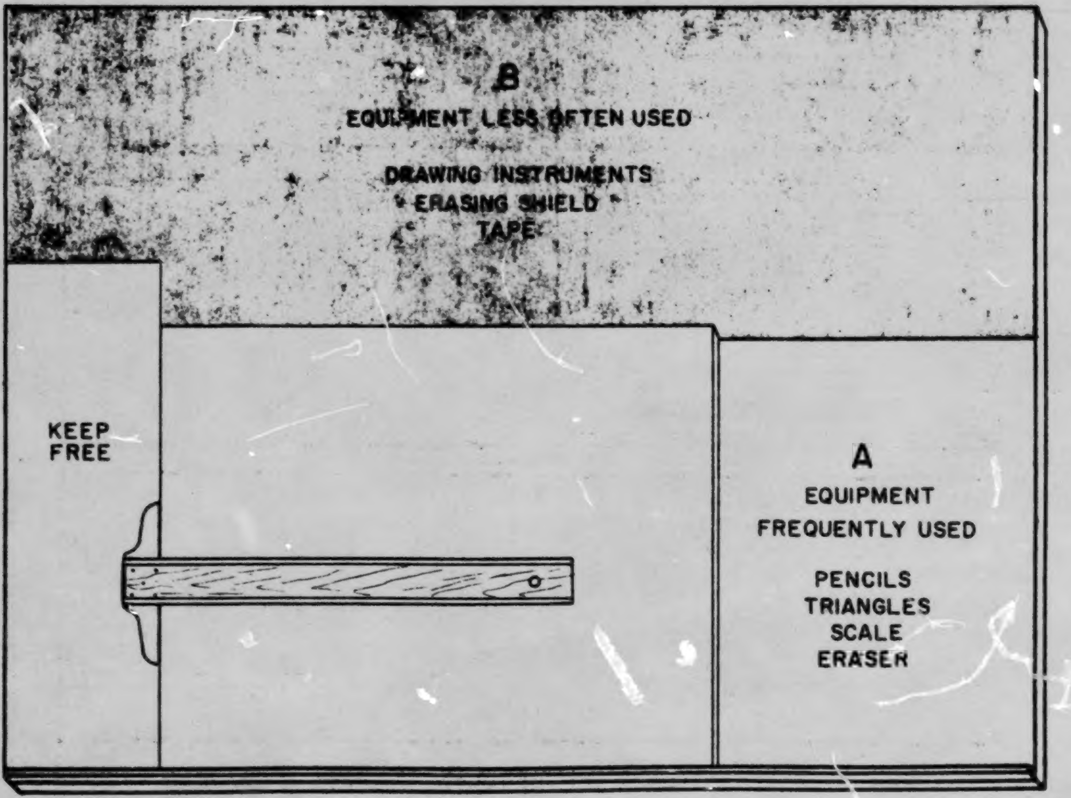

B
EQUIPMENT LESS OFTEN USED
DRAWING INSTRUMENTS
ERASING SHIELD
TAPE
KEEP
FREE
A
EQUIPMENT
FREQUENTLY USED
PENCILS
TRIANGLES
SCALE
ERASER

Fig. 4-1 Position of equipment

27

DRAWING SHEET LAYOUT

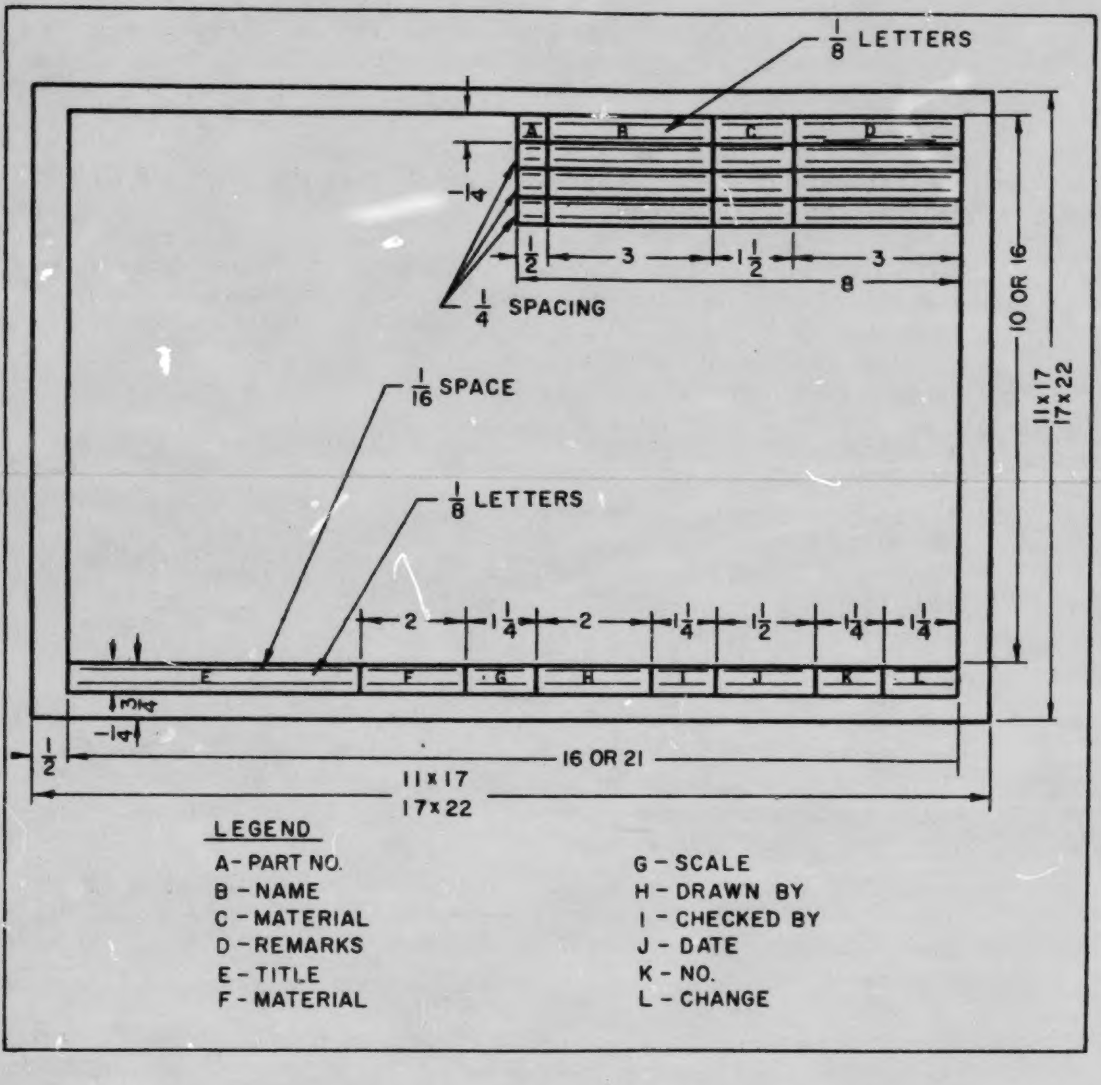

1/8 LETTERS
A
B
C
D
1/4
1/2
3
1 1/2
3
8
1/4 SPACING
10 OR 16
11x17
17x22
1/16 SPACE
1/8 LETTERS
2
1 1/4
2
1 1/4
1 1/2
1 1/4
1 1/4
E
F
G
H
I
J
K
L
3/8
1/4
1/2
16 OR 21
11x17
17x22
LEGEND
A - PART NO.
B - NAME
C - MATERIAL
D - REMARKS
E - TITLE
F - MATERIAL
G - SCALE
H - DRAWN BY
I - CHECKED BY
J - DATE
K - NO.
L - CHANGE

Fig. 4-2 Sample drawing sheet layout

The drawings to be made from the instructions in this book are to be 11" wide and 17" long. This size sheet is standard for drawings.

The step-by-step procedure which follows shows how to prepare the margin and title strip for your drawings. Read and do each detailed step carefully.

ASSIGNMENT

1. Place the drawing paper on the drawing board in the approximate center from left to right. The upper edge of the paper should be near the top of the board. Pin down one of the upper corners with drafting tape to hold the paper on the board.

2. Place the head of a T-square against the left edge of the board and slide it up to the top edge of the paper.

3. Move the paper until the top edge is parallel with the upper edge of the T-square. Then pin down the other three corners with tacks or drafting tape.

4. Measure 1/2″ toward the center of the paper from the top, then another 10″ down. Measure 1/2″ from the left edge, then another 16″ to the right.

   Holding your T-square firmly against the left-hand edge of the board, draw a line through the dot which is 1/2″ from the top and the one near the bottom of the paper.

   Then place your 30°-60° triangle against the upper edge of your T-square with the vertical side of the triangle at the left as shown in Fig. 4-3. Now draw vertical lines through the dot 1/2″ from the left edge and through the dot near the right edge. These four lines are called margin lines.

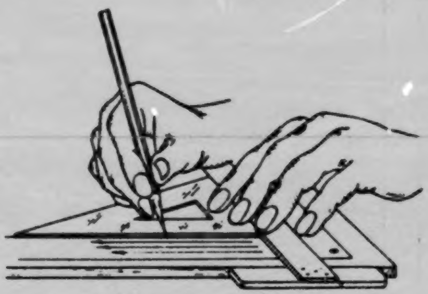


Fig. 4-3 Position of triangle for drawing vertical lines

5. Measure 1/4″ down from the upper margin and place a dot. Place three more dots below this one, each one-quarter inch apart. Draw lines through these dots from the center of the paper (8″ in from either margin) to the right margin.

6. From the right margin and along the upper margin, measure back 3″ and place a dot. Then measure 1 1/2″, another 3″ and then 1/2″, placing dots at each point. Now use your triangle, as before, and draw a line through each dot extending from the upper margin to the lowest of the four lines drawn in Step 5. This gives you your title strip.

7. Measure 1/4″ up from the bottom margin, place a dot and draw a line through the dot from margin to margin.

8. Starting at the left margin, place dots on the line just drawn, 5 1/2″, 2″, 1 1/4″, 2″, 1 1/4″, 1 1/2″, 1 1/4″ (in this order) apart. Draw vertical lines through these dots from the line they are on to the lower margin. This gives you another title strip.

9. Now prepare the title strips for lettering. In the title strip in the upper right corner, measure down from the top margin 1/16" and place a dot. Then measure down 1/8" and place another dot. Place six more dots on down the page in a like manner, each 1/8" apart.

10. Through these eight dots draw very light horizontal lines from the center of the page to the right margin. These lines are called horizontal guide lines. The guide lines are drawn to aid you with your freehand lettering.

11. Above the lower margin measure up 1/16", then 1/8". Place dots and draw light guide lines from margin to margin as in Step 10.

    At this point your instructor will tell you whether vertical or inclined lettering is to be used.

12. For vertical lettering, draw a series of vertical lines, about 1/4" apart, across the horizontal guide lines. These are called vertical guide lines.

13. For inclined lettering, a slope of 2 to 5 is used. From the upper left corner of the margin lines measure on the horizontal line two 1/4" spaces (1/2"). On the vertical line measure five 1/4" spaces (1 1/4"). Arrange your T-square and the 30° - 60° triangle as shown in Fig. 4-4. Keep the T-square stationary and lightly draw a series of sloping lines along the left side of the triangle. These lines should be about 1/4" apart and should cross the horizontal guide lines. They are called sloping guide lines.

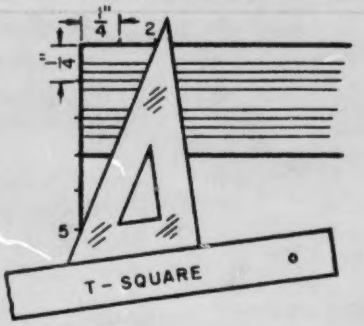


Fig. 4-4 Position of triangle for drawing sloping guide lines

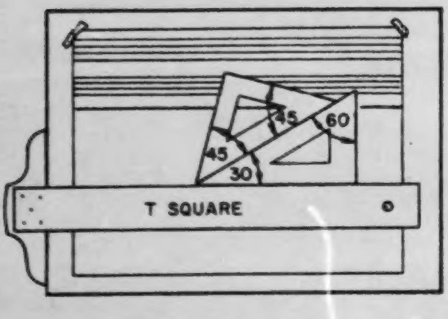


Fig. 4-5 Alternate position of triangles for drawing sloping guide lines

An alternative method for drawing sloping guide lines is to place the 30°-60° and 45° triangles on the T-square as shown in Fig. 4-5. This gives an angle of 75°. Sloping guide lines may then be quickly and easily drawn any place on the paper.

NOTE: Sloping guide lines always slope to the right whether the draftsman is left- or right-handed.

Your sheet is now ready for drawing. This standard layout will be used on each sheet in this course before a drawing is started.

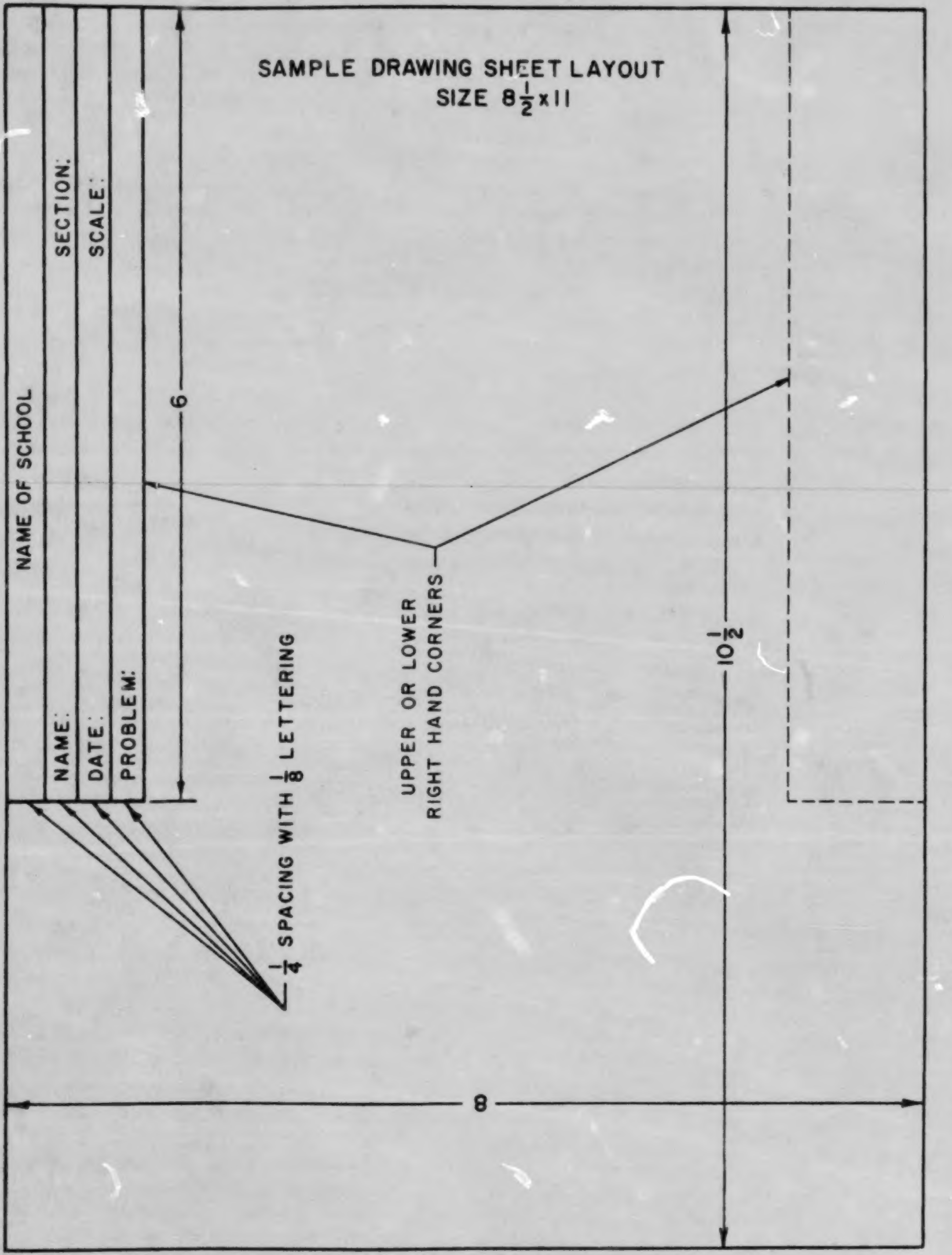

SAMPLE DRAWING SHEET LAYOUT
SIZE 8½ x 11
NAME OF SCHOOL
SECTION:
SCALE:
NAME:
DATE:
PROBLEM:
6
¼ SPACING WITH ⅛ LETTERING
UPPER OR LOWER
RIGHT HAND CORNERS
10½
8

Fig. 4-6

Unit 5 LETTERING

VERTICAL GOTHIC

ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$

SLANT GOTHIC

ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{7}{16}$

VERTICAL ARCHITECTURAL

ABCDEFGHIJKLMNOPQRST
UVWXYZ

ABCDEFGHIJKLMNOPQRST
UVWXYZ

SLANT ARCHITECTURAL

ABCDEFGHIJKLMNOPQRST
UVWXYZ

ABCDEFGHIJKLMNOPQRST
UVWXYZ

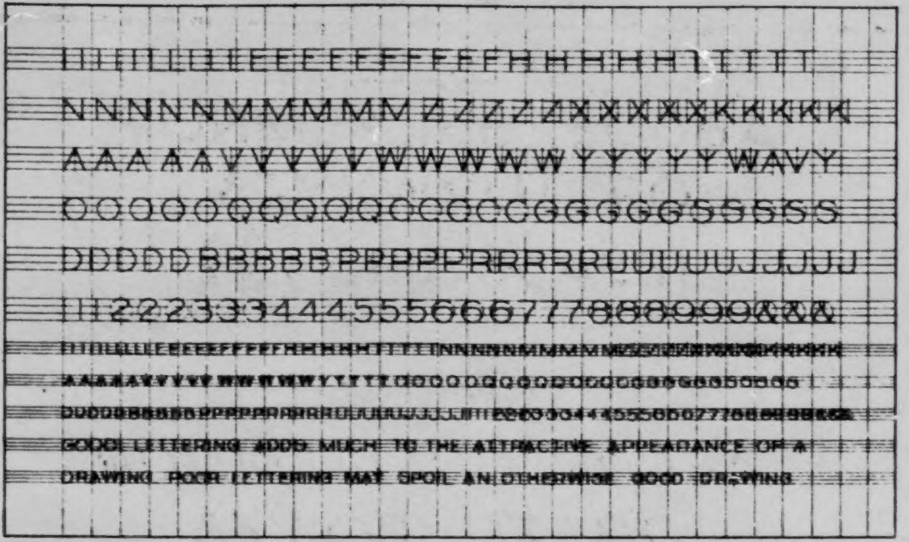

IIIIILLLLLEEEEEFFFFFHHHHHTTTTT
NNNNNMMMMMZZZZZXXXXXKKKKK
AAAAAVVVVVWWWWWYYYYYWAVY
OOOOOQQQQQCCCCCGGGGGSSSSS
DDDDDBBBBBPPPPPRRRRRUUUUUJJJJJ
1112223334445556667778889999&&&
GOOD LETTERING ADDS MUCH TO THE ATTRACTIVE APPEARANCE OF A
DRAWING. POOR LETTERING MAY SPOIL AN OTHERWISE GOOD DRAWING

Fig. 5-1 Vertical, single-stroke Gothic lettering

LETTERING PROCEDURES

You have been told that drafting is a language which uses lines, symbols, dimensions and notations to accurately describe an object. The lines and symbols are drawn in with drawing instruments and tools; the dimensions, notes, titles, bills of materials and specifications are lettered on the drawing freehand. Lettering is used instead of writing because it is more legible. For general use on drawings, single-stroke Gothic letters have been adopted. These letters are formed by straight and curved strokes of uniform width. With practice, they can be drawn with ease and rapidity.

Two styles of single-stroke Gothic letters are in general use: the vertical style in which all letters are capitals and the inclined style which may be all capitals, or capitals and lower-case.

The purpose of this lettering instruction sheet is to teach you the shape of the different letters and numerals, also the sequence and direction of the strokes used to form them. Horizontal guide lines are always used to get a uniform height for the letters. For the vertical style of lettering, vertical guide lines are used. The vertical strokes of the letters should be parallel with the vertical guide lines.

For the inclined style of lettering, sloping guide lines are used. The letters should be compared with the sloping guide lines so that the inclination of all of the letters will be uniform. A 2H or a 3H pencil with a conical point should be used for lettering.

Good lettering adds much to the attractive appearance of a drawing. Careless or poor lettering may spoil an otherwise good drawing. Skill and speed in lettering can only be acquired through painstaking practice.

While this book contains a Assignment sheet for vertical single-stroke Gothic letters and another for inclined single-stroke Gothic letters, it is not intended that you do both. Consult your instructor as to which style is preferred.

SINGLE-STROKE VERTICAL CAPITALS AND NUMERALS

The shapes of the letters can be learned best by a study of the vertical Capitals. These are arranged in groups in Fig. 5-2 to 5-7

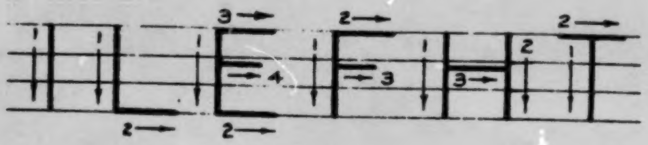


Fig. 5-2 Letters formed with horizontal and vertical strokes

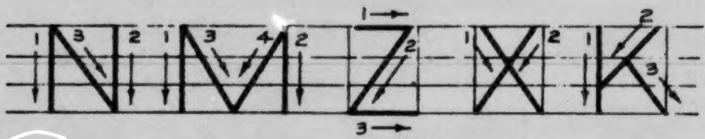


Fig. 5-3 Letters formed with vertical, horizontal and oblique lines

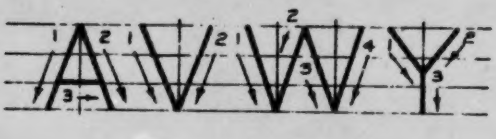


Fig. 5-4 Letters formed with oblique strokes

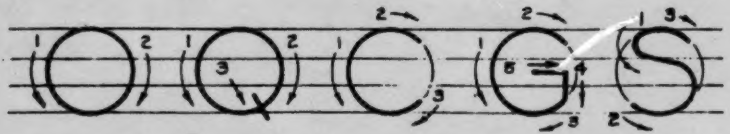


Fig. 5-5 Letters formed with curved strokes

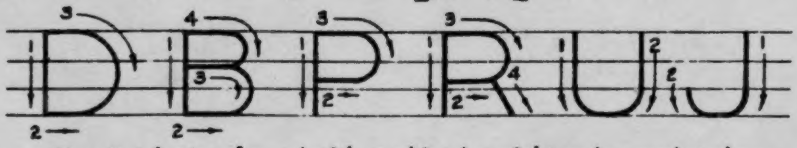


Fig. 5-6 Letters formed with combined straight and curved strokes

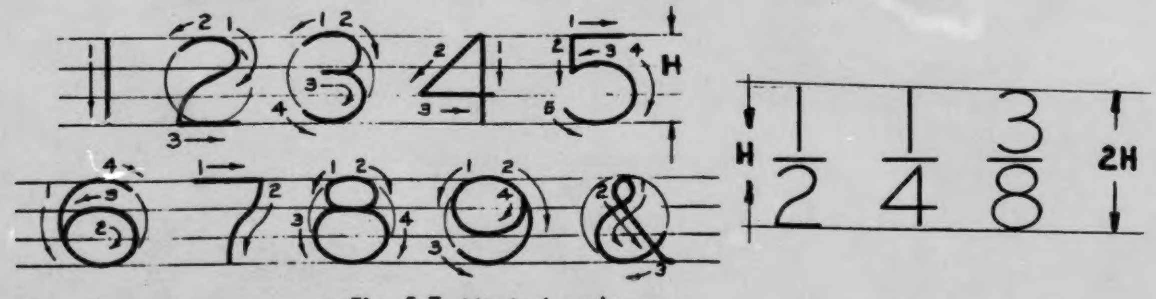


Fig. 5-7 Vertical numbers

INCLINED CAPITAL LETTERS AND NUMERALS

The order and direction of the strokes and the proportions of the inclined capital letters and numerals are the same as those for the vertical characters. The methods of drawing guide lines for inclined capital letters are given in Fig. 5-9

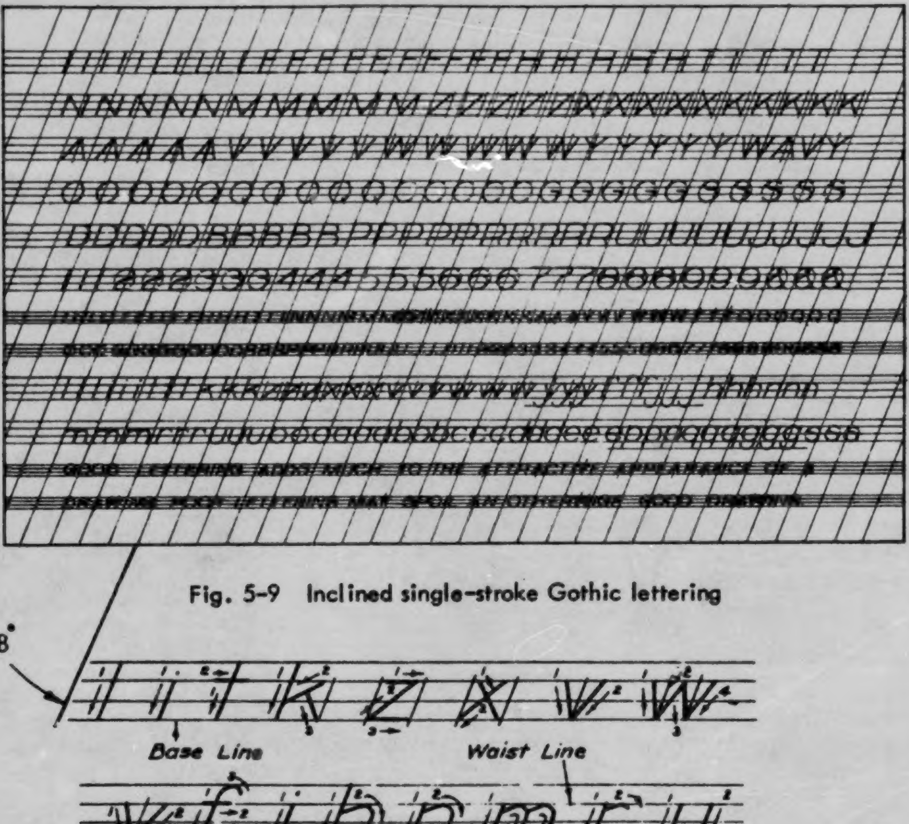

GOOD LETTERING ADDS MUCH TO THE ATTRACTIVE APPEARANCE OF A
DRAWING POOR LETTERING MAY SPOIL AN OTHERWISE GOOD DRAWING

Fig. 5-9 Inclined single-stroke Gothic lettering

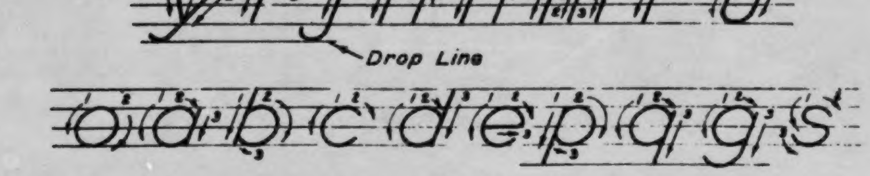
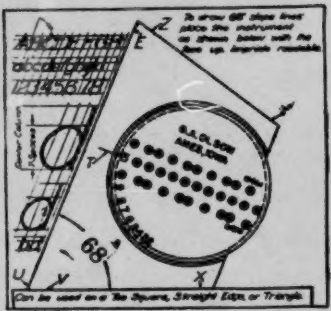

68°
Base Line
Waist Line
Drop Line

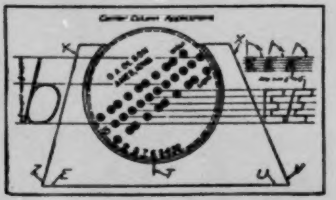
Fig. 5-10 Inclined lower-case letters

Refer to the lower-case letters shown above. For practice lettering, they are divided into three groups. The first group is made with straight line strokes; the second, hooked strokes; and, the third group is based on the inclined ellipse. The body of these letters is made 2/3 of the height of corresponding capitals. The letters b, d, f, h, k, l and t, ascend above the waist line. The letters g, j, p, q and y, descend below the base line.

Ames Lettering Instrument



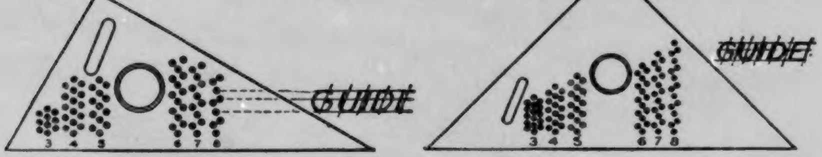
Transparent Plastic Disc in a Plastic Frame



The Ames Lettering Angle is the only instrument of its kind that has holes spaced for three different systems of guide lines; the ⅔ is usually used by civil engineers while the ⅗ is used by those using the Reinhardt system of lettering. The holes in the middle column are equally spaced for block lettering or cross hatching. The instrument is used in the same manner as the Braddock Angle described below. **The vertical height between the guide lines may be regulated by revolving the disc in the frame.**

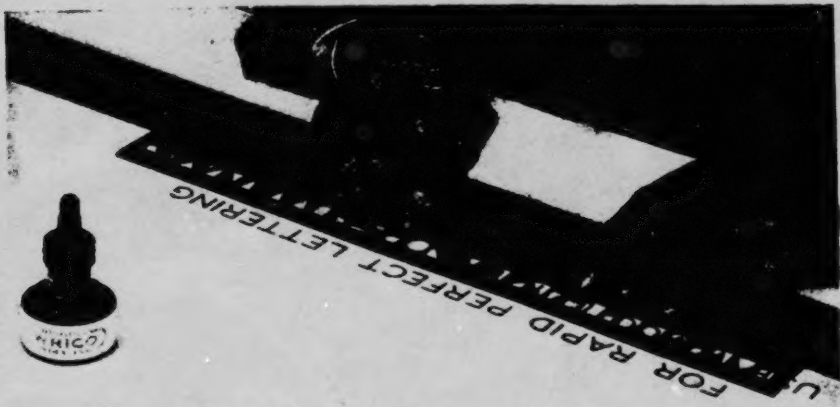
Braddock Lettering Angles

of Transparent Plastic



A combination of a fine triangle and useful lettering instrument.

The Braddock Lettering Angle is designed to rule accurately spaced guide lines for lettering drawings, etc. Practically any desired spacing or guide lines may be obtained by inserting pencil point through the proper hole and sliding the angle along the T Square, then placing the point through another hole and sliding back.

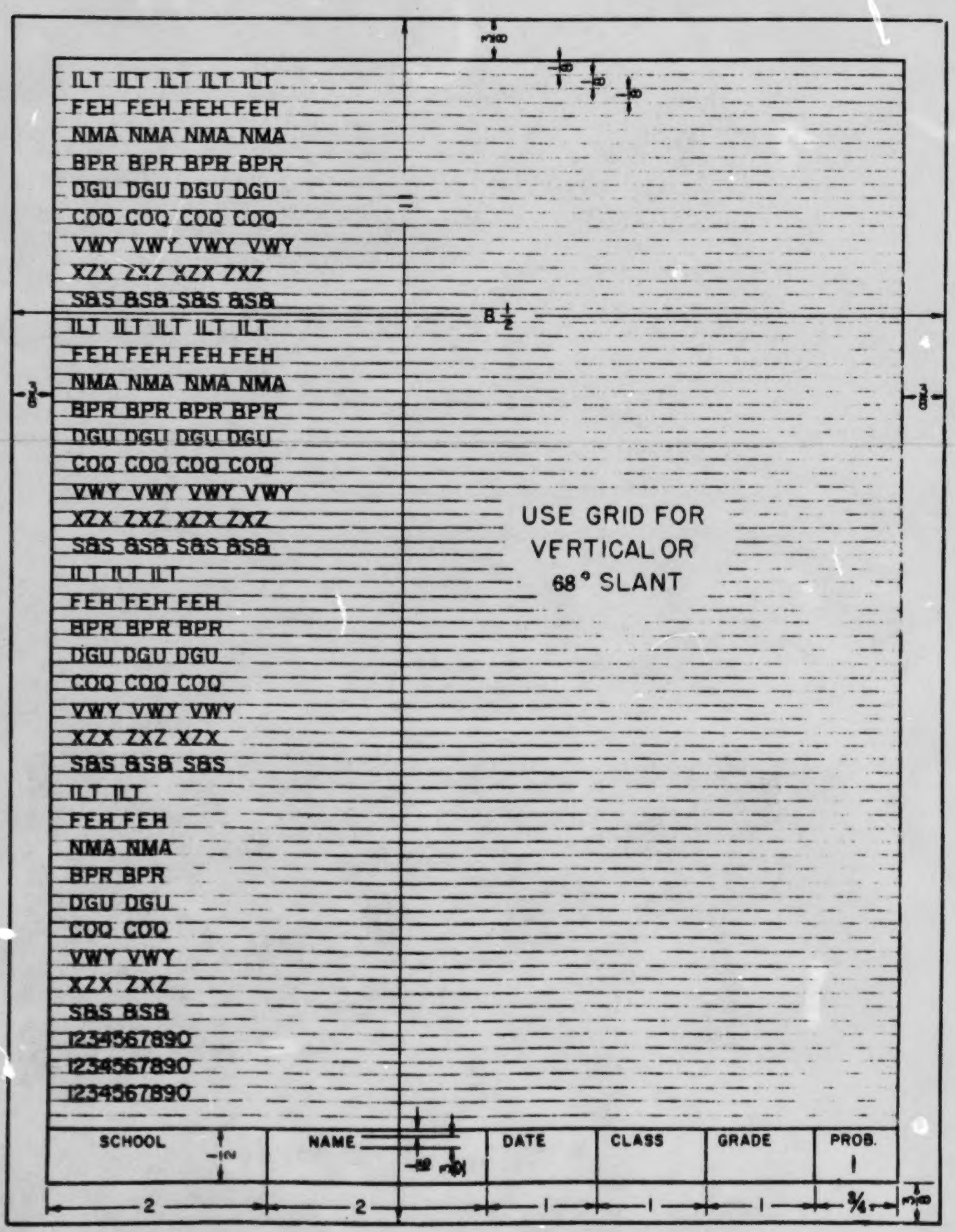


Wrico Lettering Guides

To use Wrico Lettering Guides effectively requires neither skill nor previous experience. No preliminary adjustments are necessary before the lettering may be done. The Wrico Lettering Pen is not a machine but is a pen which is held in the hand and used in an easy and natural position.

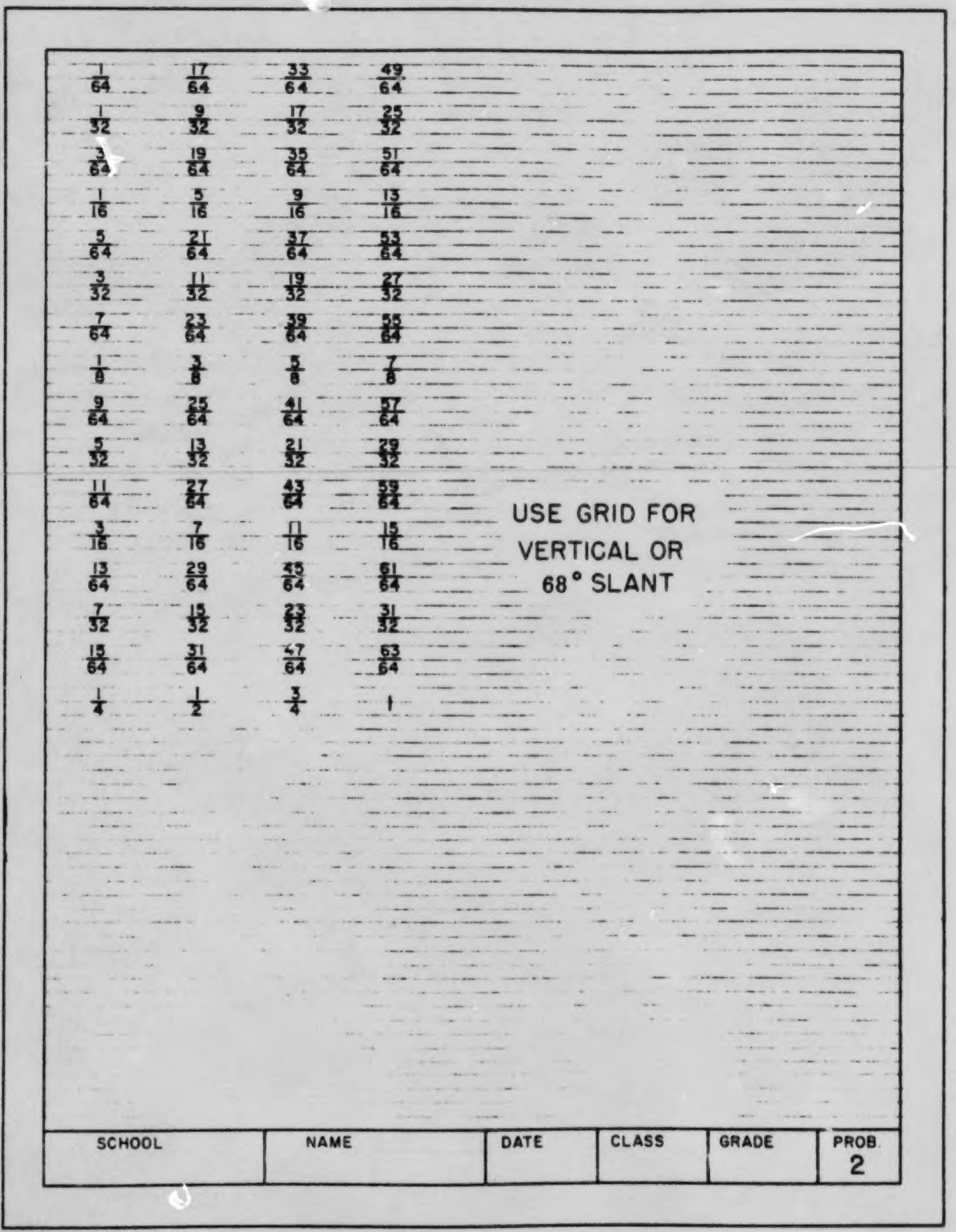
ASSIGNMENT

Lay out a sheet like the one below, using guide lines as shown, and completing lettering given. Then submit your drawing for final approval.


ILT ILT ILT ILT ILT
FEH FEH FEH FEH
NMA NMA NMA NMA
BPR BPR BPR BPR
DGU DGU DGU DGU
COQ COQ COQ COQ
VWY VWY VWY VWY
XZX ZXZ XZX ZXZ
SBS BSB SBS BSB
8 1/2
3/8
USE GRID FOR
VERTICAL OR
68° SLANT
1234567890
SCHOOL
NAME
DATE
CLASS
GRADE
PROB.
1
2
2
1
1
1
3/4

ASSIGNMENT

2. Lay out a sheet like the one below, using guide lines as shown, and completing all lettering given. Then submit your drawing for final approval.


1/64 17/64 33/64 49/64
1/32 9/32 17/32 25/32
3/64 19/64 35/64 51/64
1/16 5/16 9/16 13/16
5/64 21/64 37/64 53/64
3/32 11/32 19/32 27/32
7/64 23/64 39/64 55/64
1/8 3/8 5/8 7/8
9/64 25/64 41/64 57/64
5/32 13/32 21/32 29/32
11/64 27/64 43/64 59/64
3/16 7/16 11/16 15/16
13/64 29/64 45/64 61/64
7/32 15/32 23/32 31/32
15/64 31/64 47/64 63/64
1/4 1/2 3/4 1
USE GRID FOR
VERTICAL OR
68° SLANT
SCHOOL
NAME
DATE
CLASS
GRADE
PROB.
2

Unit 6 GEOMETRIC CONSTRUCTIONS

The purpose of the geometric constructions in this section of the manual is to present some short, accurate methods of drawing parallel lines, perpendiculars and tangent arcs; and the construction of triangles and polygons under varying conditions.

These constructions are frequently used by draftsmen and other craftsmen in their daily work. Many are useful in the layout of large sheet metal patterns, airplane layout work and in other applications where the T-square and triangles cannot be used in the conventional manner.

For this reason, it is intended that the geometric constructions which follow be made without the use of a T-square. Only a straightedge, compass, dividers, pencil and paper should be used.

In each construction some part or parts are given such as a line, an angle, an arc, a point or some combination of these.

The given portion of each construction should be drawn with bold lines.

The lines in the construction of each should be fine lines.

Those lines required to complete the construction should be bold and heavier than the construction lines.

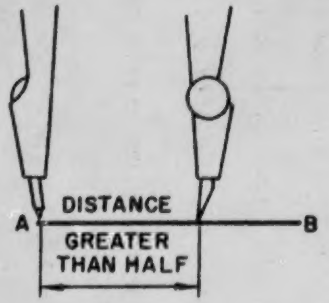
A general list of points to be remembered in making geometric constructions follows.

- A point has no dimensions. It has position only.
- A straight line has position, direction and length, but not width or thickness.
- A perpendicular is a straight line at a right angle to another straight line.
- Parallel lines are equidistant for their entire length.
- Bisect means to divide in two equal parts.
- An angle is the space, or opening, between two straight lines that meet.
- A right angle contains 90°.
- An acute angle contains less than 90°
- An obtuse angle contains more than 90° and less than 180°

- A reflex angle contains more than 180°.
- A triangle is a figure having three angles and three sides.
    - ✓ A scalene triangle has unequal sides and unequal angles.
    - ✓ An isosceles triangle has two equal sides and two equal angles.
    - ✓ An equilateral triangle has three equal sides, hence there are three equal angles.
    - ✓ A right triangle has one right angle.
- A circle is a closed curved line on a plane, such that every part is equidistant from a point which is called the center.
- An arc is a part of a circle.
- A radius is a straight line (or distance) from the center to a circle or an arc.
- A diameter is a straight line (or distance) from one side of a circle, through the center to the other side.
- A polygon is a plane closed figure having sides and angles.
- A regular polygon has equal sides and angles.
    - ✓ A square is a regular polygon with 4 equal sides and 4 right angles.
    - ✓ A pentagon is a regular polygon with 5 sides and angles.
    - ✓ A hexagon is a regular polygon with 6 sides and angles.
    - ✓ A heptagon is a regular polygon with 7 sides and angles.
    - ✓ An octagon is a regular polygon with 8 sides and angles.
    - ✓ A nonagon is a regular polygon with 9 sides and angles.
    - ✓ A decagon is a regular polygon with 10 sides and angles.
- A straight line is tangent to an arc when the line touches the arc at a single point and does not intersect the arc.
- Arcs are tangent to one another when they touch at a single point and do not intersect.

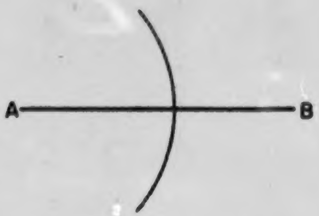
BISECT A GIVEN LINE

STEP 1


DISTANCE
A
B
GREATER
THAN HALF

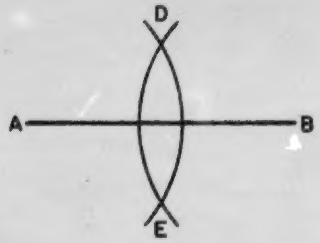
Set compass.

STEP 2



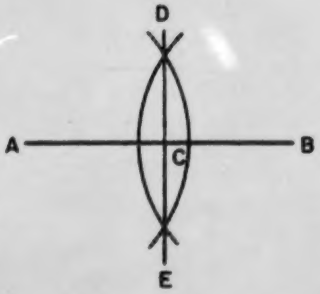
Swing arc from point A.

STEP 3



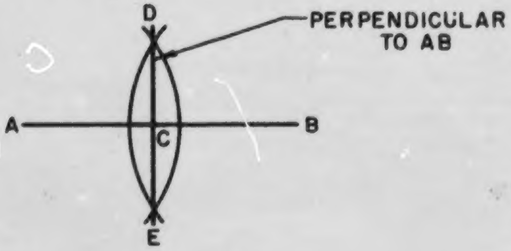
Swing an equal arc from point B to intersect at D and E.

STEP 4



Draw a line through D and E to intersect line AB at C.

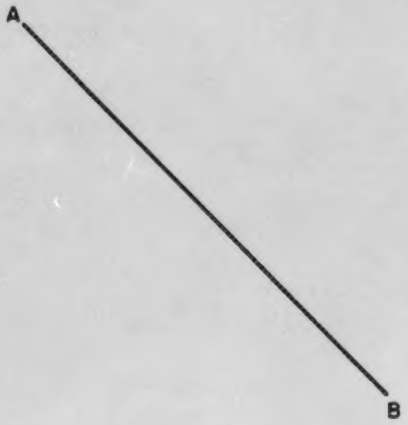
STEP 5


D
PERPENDICULAR
TO AB
A
C
B
E

AC equals CB.

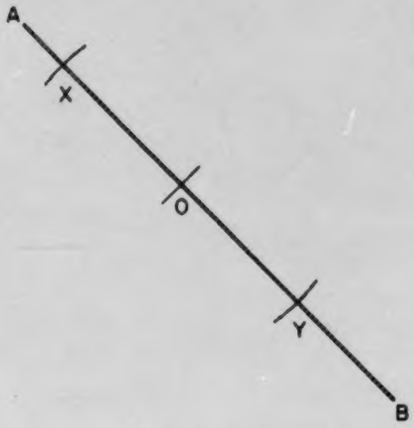
CONSTRUCT A PERPENDICULAR TO A GIVEN LINE

STEP 1



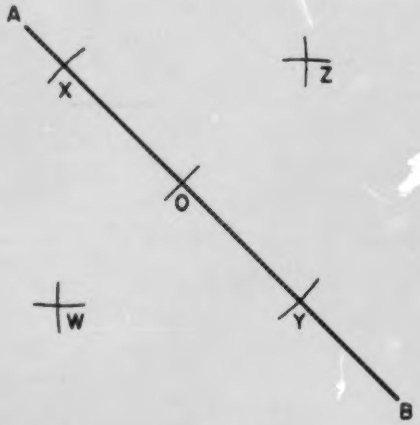
Given line AB

STEP 2



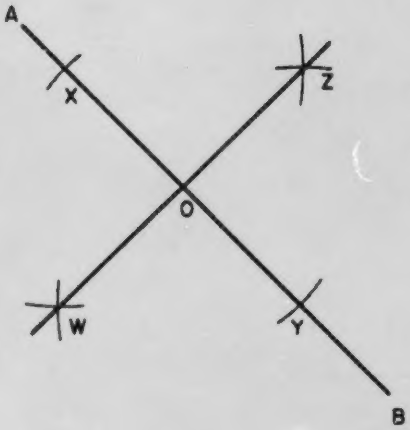
With any point "O" as center, swing equal arcs OX, OY.

STEP 3



With an arc greater than OY, swing equal arcs from X and Y to intersect at W and Z.

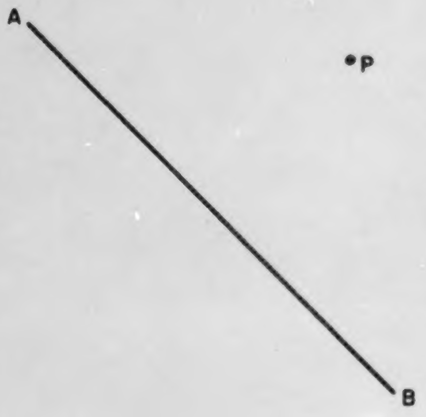
STEP 4



Construct line WOZ perpendicular to line AB at point "O".

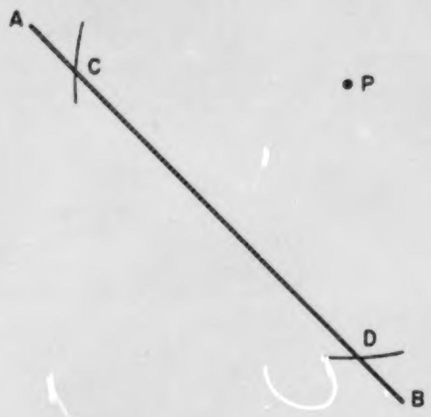
CONSTRUCT A PERPENDICULAR TO A GIVEN LINE FROM A POINT

STEP 1



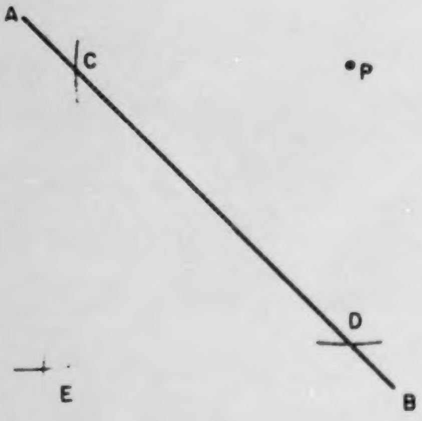
Given line AB and point P

STEP 2



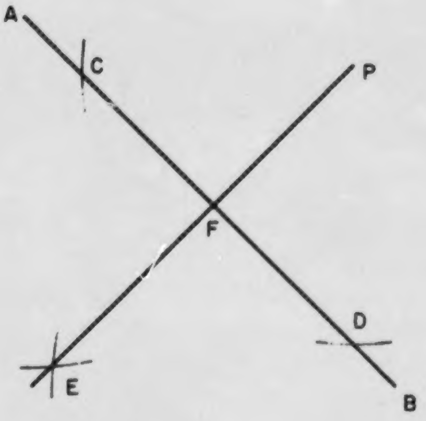
With P as a center, swing an arc to intersect AB at C and D.

STEP 3



With C and D as centers, swing equal arcs to intersect at E

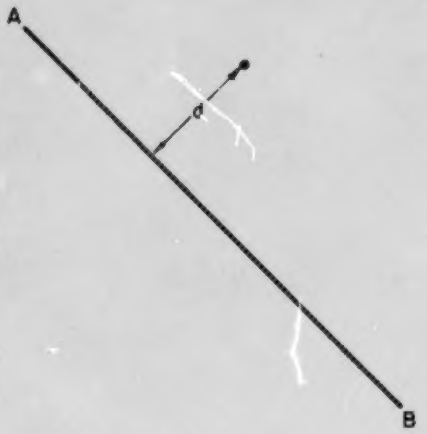
STEP 4



Construct PE perpendicular to AB at F.

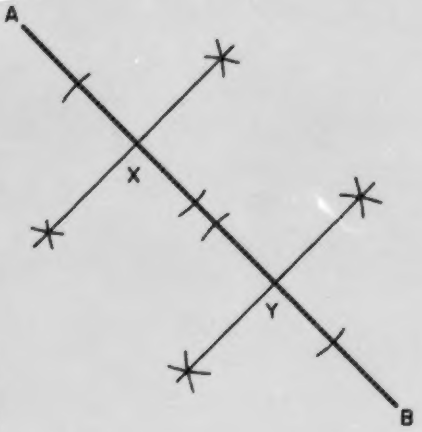
DRAW A LINE PARALLEL TO A GIVEN LINE

STEP 1



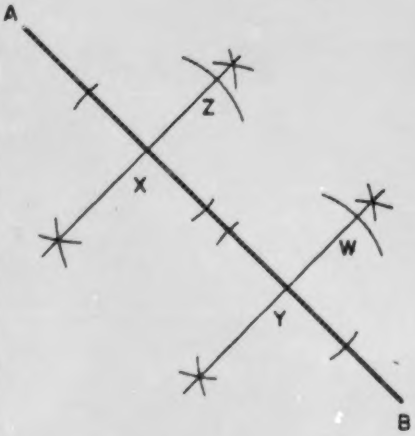
Given line AB.
A parallel line is to be constructed distance "d" away from line AB.

STEP 2



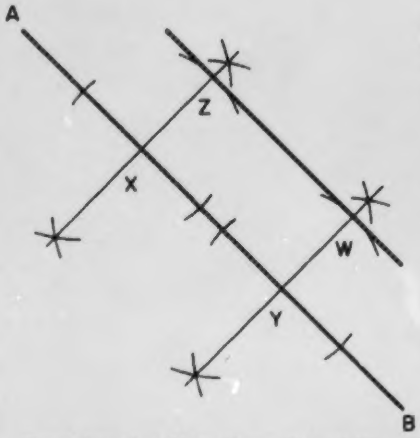
Construct perpendiculars at any points X and Y.

STEP 3



With X and Y as vertices, swing arcs XZ and YW equal to distance "d".

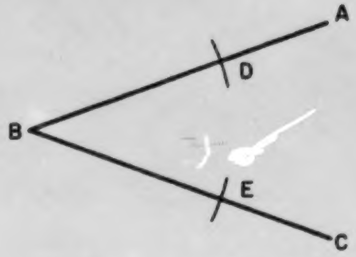
STEP 4



Construct a line thru Z and W. This line is parallel to line AB. Note: The parallel line can be constructed on either side of AB.

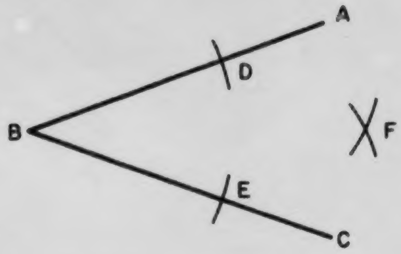
BISECT A GIVEN ANGLE

STEP 1



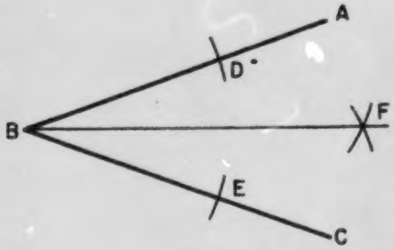
Given angle ABC, swing any arc from B through D and E.

STEP 2



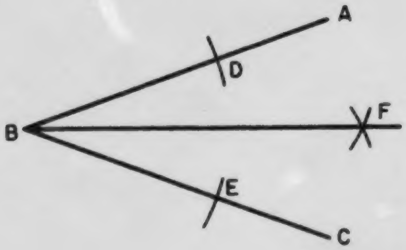
Swing equal arcs from D and E to intersect at F.

STEP 3



Draw line BF.

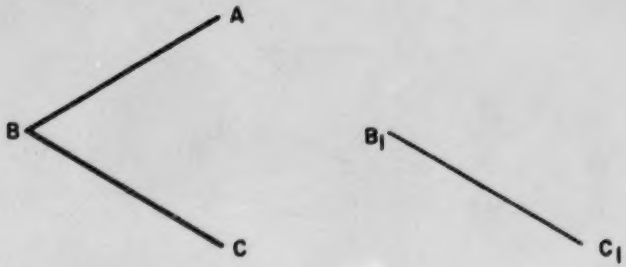
STEP 4



Line BF bisects angle ABC.

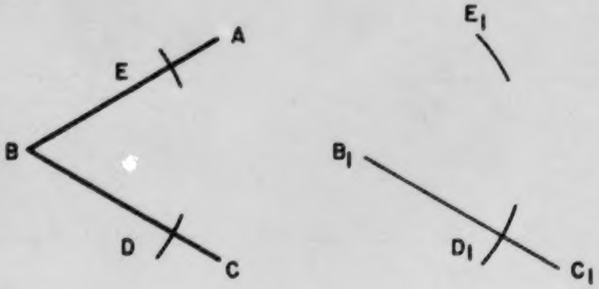
CONSTRUCT AN ANGLE EQUAL TO A GIVEN ANGLE

STEP 1



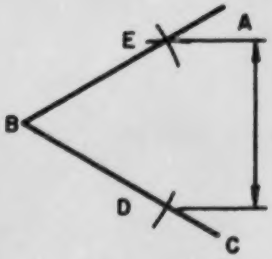
Given angle ABC. Draw B_1C_1 = side BC.

STEP 2


E1
E
A
B
B1
D
C
D1
C1

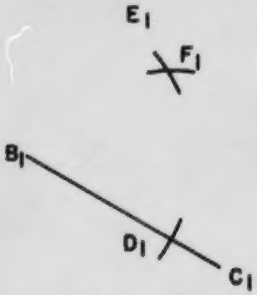
With B and B_1 as vertices, swing equal arcs D and E, and D_1 and E_1.

STEP 3



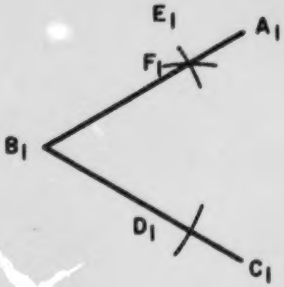
Set compass to DE.

STEP 4


E1
F1
B1
D1
C1

From D_1, swing arc F_1 to intersect E_1.

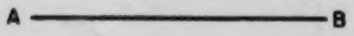
STEP 5


E1
A1
F1
B1
D1
C1

Draw B_1F_1 extended. $\angle A_1B_1C_1 = \angle ABC$.

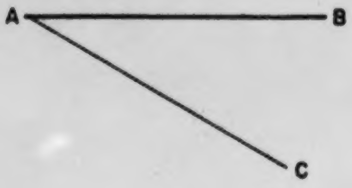
DIVIDE A LINE INTO AN EQUAL NUMBER OF PARTS

STEP 1



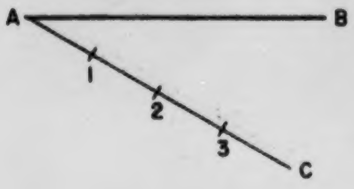
AB is to be divided into 3 equal parts.

STEP 2



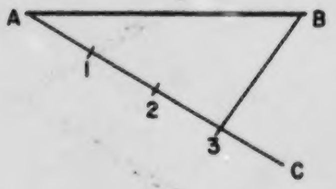
Draw line AC at any angle.

STEP 3



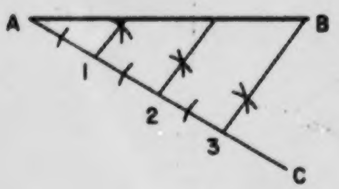
Step off 3 equal spaces on line AC.

STEP 4



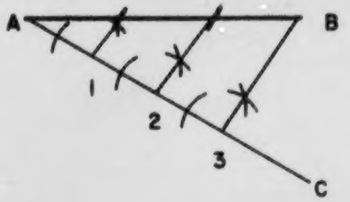
Connect end points B and 3.

STEP 5



Construct angles at 1 and 2 equal to 3.
Legs of the angles to intersect line AB.

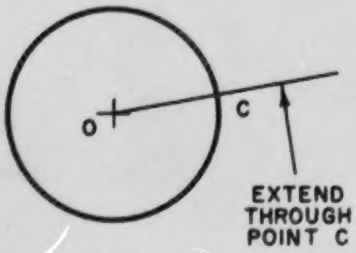
STEP 6



Line AB is divided into 3 equal parts.

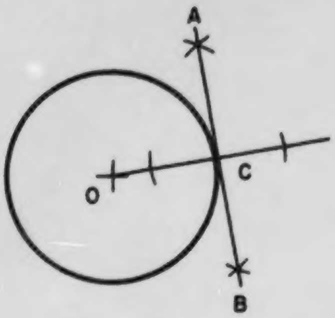
CONSTRUCT A TANGENT TO A GIVEN POINT ON A CIRCLE

STEP 1


O
C
EXTEND THROUGH POINT C

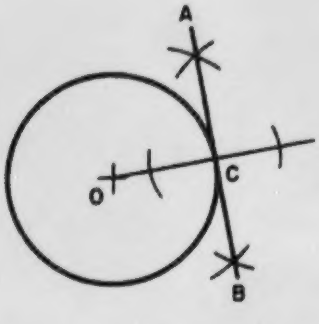
Draw radius OC extended through C.

STEP 2



Construct AB perpendicular at C.

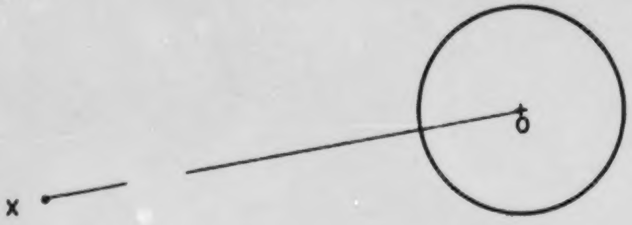
STEP 3



Line AB is tangent at C.

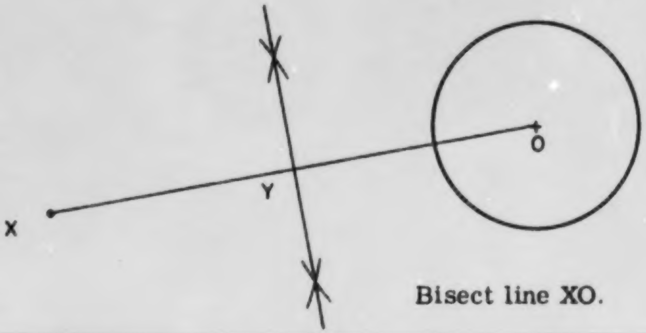
CONSTRUCT A TANGENT TO A CIRCLE FROM A GIVEN POINT

STEP 1



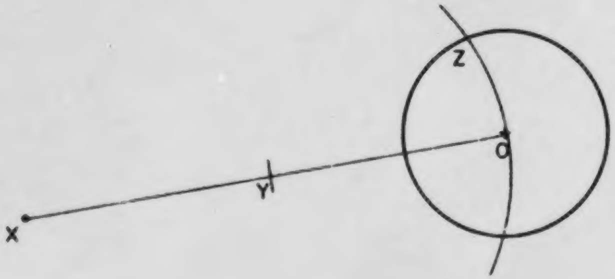
Draw line XO.

STEP 2



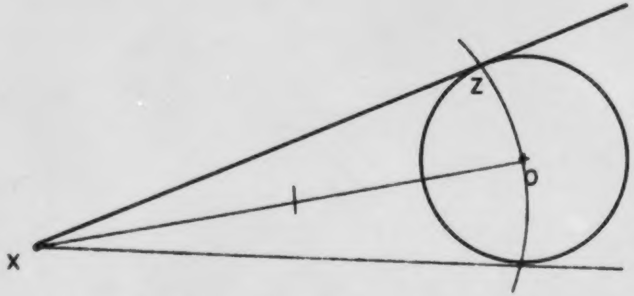
Bisect line XO.

STEP 3



Draw arc YO to intersect circle at Z.

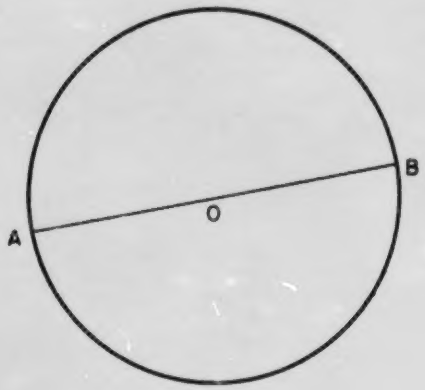
STEP 4



Draw tangent line XZ. Note the two possible tangents.

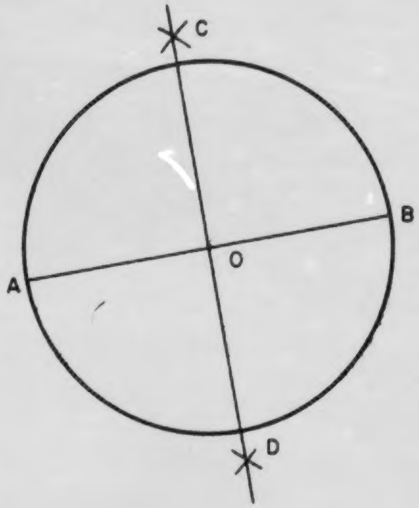
INSCRIBE A SQUARE IN A CIRCLE

STEP 1



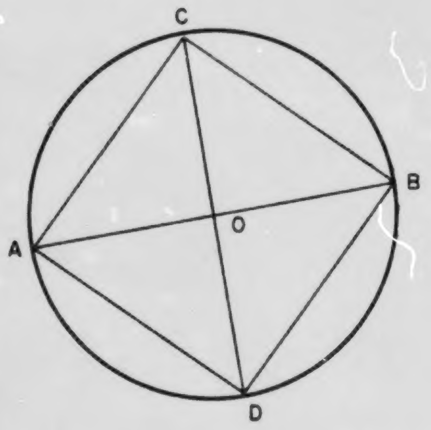
Draw any diameter AB.

STEP 2



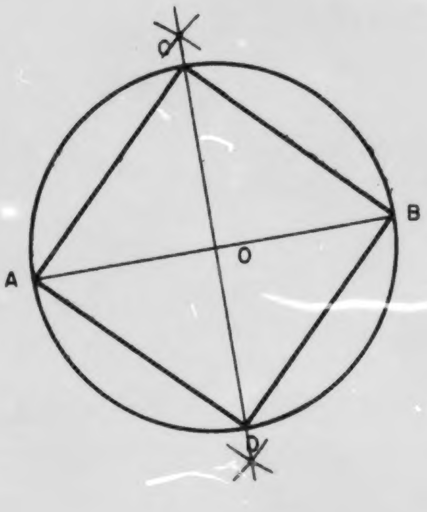
Construct diameter CD perpendicular to AB.

STEP 3



Connect points A, C, B, and D

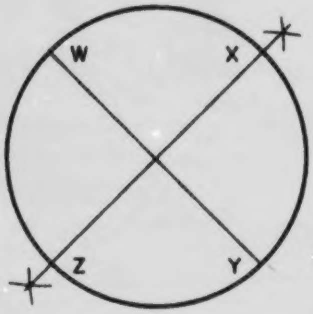
STEP 4



The square ACBD is inscribed in circle O.

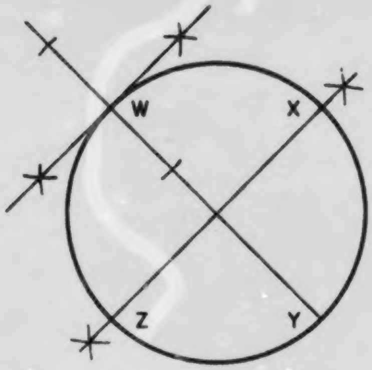
CIRCUMSCRIBE A SQUARE ABOUT A CIRCLE

STEP 1



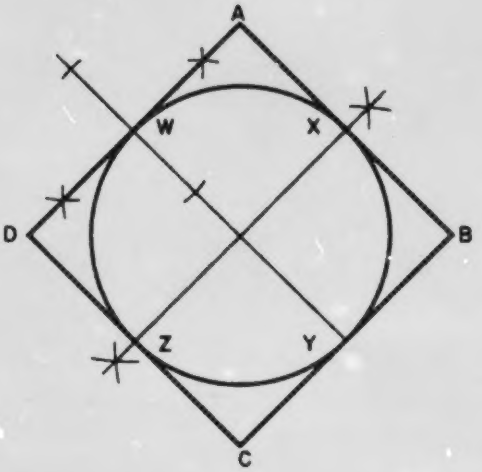
Draw any diameter WY.
Construct diameter XZ perpendicular to WY.

STEP 2



Construct a tangent at W.

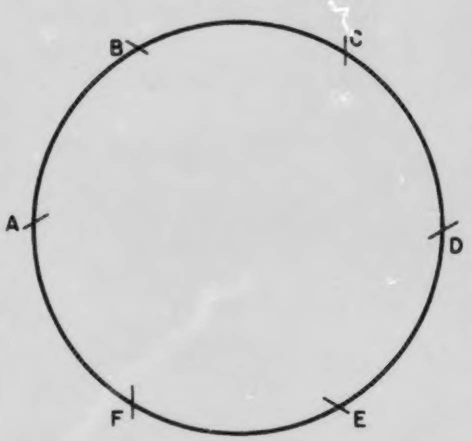
STEP 3



Construct tangents at X, Y, and Z.
ABCD is a square circumscribed about the circle.

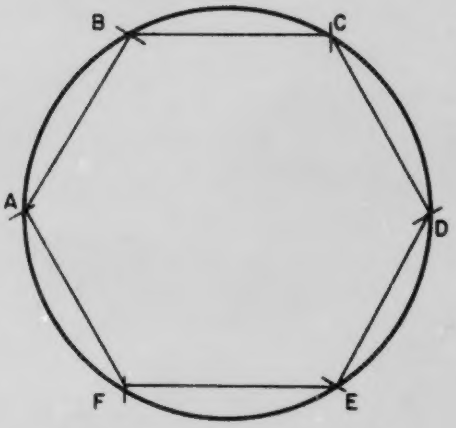
INSCRIBE A HEXAGON IN A CIRCLE

STEP 1



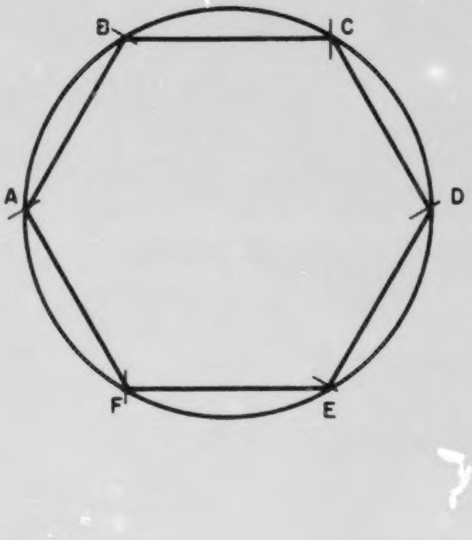
Using the radius of the circle as the compass setting, step off 6 consecutive spaces on the circumference.

STEP 2



Connect the consecutive points.

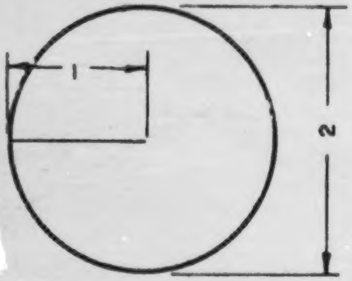
STEP 3



ABCDEF is the required inscribed hexagon.

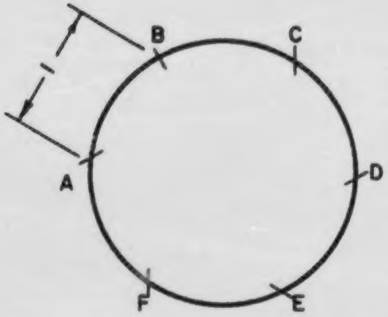
CIRCUMSCRIBE A HEXAGON ABOUT A CIRCLE

STEP 1



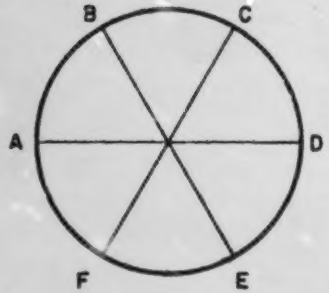
Draw circle of given diameter. Maintain compass setting.

STEP 2



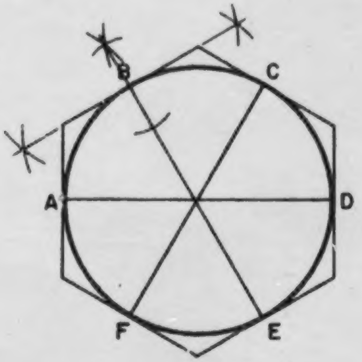
Step off 6 consecutive, equal arcs on the circle.

STEP 3



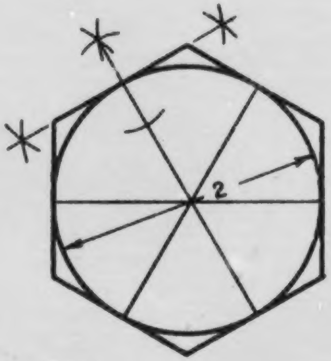
Draw 6 radii to points of intersection.

STEP 4



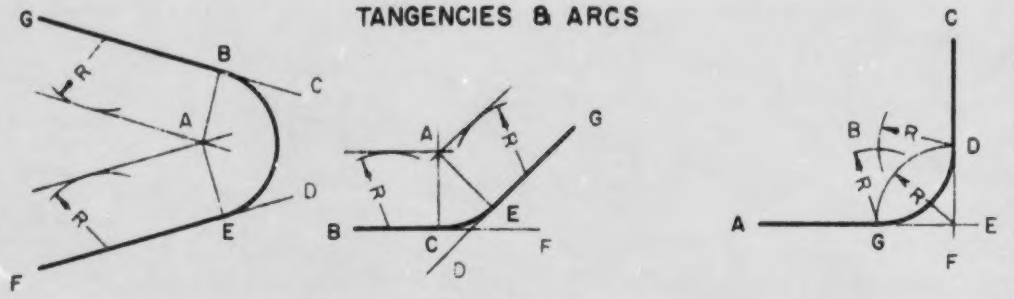
Draw tangents to 6 radii.

STEP 5

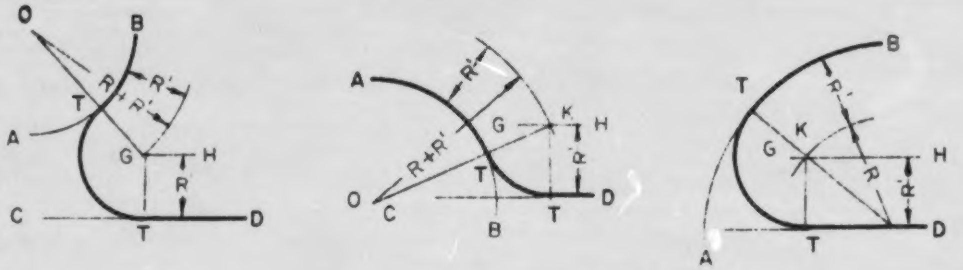


Hexagon circumscribes circle.

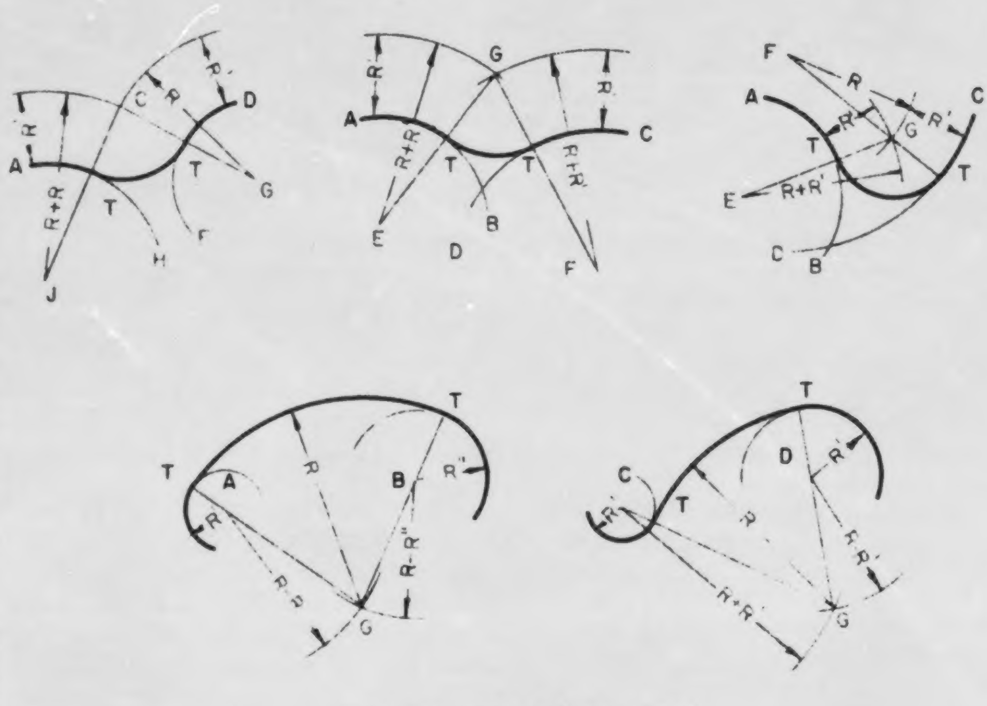
TANGENCIES & ARCS


G
B
C
R
A
D
R
E
F
A
R
G
R
B
C
E
F
D
C
B
R
D
R
R
A
G
E
F

ARC TANGENT TO TWO LINES


O
B
R+R'
R'
T
A
G
H
R
C
T
D
A
R'
G
K
H
R+R'
T
R
O
C
B
T
D
B
T
R'
K
G
H
R
R
A
T
D

ARC TANGENT TO AN ARC AND LINE


R'
C
R
D
A
R
T
G
R+R
T
H
F
J
G
R
R
A
C
R+R
T
T
R+R'
E
B
D
F
F
R
A
R'
G
R'
C
T
E
R+R'
T
C
B
T
T
A
R
B
R''
R
R-R
R-R''
G
T
C
D
R'
R
T
R
R-R'
R+R'
G

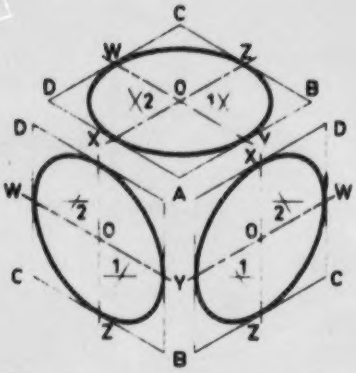
ARC TANGENT TO TWO ARCS

ASSIGNMENT

1. Bisect a 4″ line.
2. Bisect a 30° angle.
3. Bisect a 75° angle.
4. Bisect a 105° angle.
5. Construct a perpendicular to a 3″ line AB at a point 1 1/4″ from A.
6. Construct a perpendicular to a 3″ line AB from a point 1 1/8″ from A and 1 3/16″ above line AB.
7. Draw a line parallel to a 3″ line AB. The parallel line is to be constructed 1 1/8″ from AB.
8. Divide a 3″ line AB into 5 equal parts.
9. Construct a tangent to a circle whose radius is 1 3/16″ from a point on the circle.
10. Construct a tangent to a circle whose radius is 1 5/32″ from a point 3 3/4″ from the center of the circle.
11. Inscribe a square in a circle whose radius is 1 7/32″.
12. Circumscribe a square about a circle whose diameter is 2 5/8″.
13. Inscribe a hexagon in a circle whose diameter is 2 5/8″.
14. Circumscribe a hexagon about a circle whose radius is 1 7/32″.
15. Draw a circle through 3 points.

    Directions:

    1. Locate any 3 points A, B and C about 2″ apart, but not in a straight line.
    2. Connect points A, B and C.
    3. Construct the perpendicular. Bisectors of these 3 lines are to intersect at one point "O"
    4. The intersection of these perpendicular bisectors at "O" is the center of a circle, which should pass through the 3 points. With "O" as the center, draw a circle to pass through the 3 points A, B and C.
    5. Label points A, B, C and O.
16. Repeat steps in Problem 15. Do this construction with 3 points about 3 1/2″ apart.



FOUR-CENTERED APPROXIMATION METHOD
FOR CONSTRUCTING ISOMETRIC CIRCLES

1. Draw the appropriate centerlines, depending upon the view in which the circle is to be drawn.

2. Determine the radius of the circle to be drawn. From the intersection of the centerlines (point "O"), mark off the distance equal to the radius in both directions of point "O", on each centerline. These will be points W, X, Y and Z.

3. Through points W and Y, draw lines parallel to the vertical centerline. Through points X and Z, draw lines parallel to the other centerline.

   Thus, the parallelogram ABCD is formed.

   Note: Only the corners at A and C (vertices of the obtuse angles) will be used in the following constructions.

4. With A as vertex, swing arc WZ.

5. With C as vertex, swing arc XY.

6. Locate the center for arc YZ by drawing lines AZ and CY to intersect at point 1. With point 1 as vertex, draw arc YZ.

7. Locate the center for arc WX by drawing lines CX and AW to intersect at point 2.

PLEASE NOTE:

1. The 4 centers for the 4 arcs are points A, C, 1 and 2.
2. The elliptical or egg shape of the isometric circle follows the pattern of the parallelogram.
3. The whole isometric circle falls within the parallelogram and is tangent to the 4 sides of the parallelogram at the mid-point of each side.

Unit 7 ORTHOGRAPHIC CONCEPT

The drawings made by draftsmen are not at all like those usually drawn by an artist. The aim of the artist is to draw or paint a picture which will give the same mental impression that one would get when looking at the subject itself. For example, if an artist were to draw a picture of a rectangular block he would draw it as it appears to him from a definite point of view. The picture might be like that shown in Fig. 7-1.

The picture suggests the form of the block but it does not show the actual shape of the surfaces. Each surface on the block is a rectangle: those surfaces shown in the picture are not rectangular. The edges of the block meet at the corners and form right angles, but there are no right angles in the picture. Also, those lines in the picture which represent the edges of the block cannot be drawn their exact lengths. If they were drawn their exact lengths, the picture would not look right. A picture, therefore, cannot show the actual shape or exact size of an object.

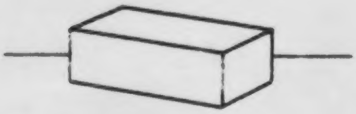


Fig. 7-1 Pictorial drawing

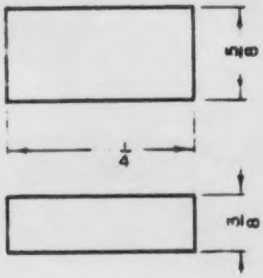


Fig. 7-2 Working drawing

Picture drawings are not suitable for manufacturing purposes because a workman in a factory must know the actual shape and the exact dimensions of the article he is to make.

Working drawings, as made by the draftsman, describe accurately the shape details and dimensions of any part to be manufactured. A working drawing of the rectangular block is shown in Fig. 7-2.

In this working drawing, the lower rectangle represents the front surface of the block. Since it is the surface of the block which is seen from a point directly in front of it, it is called a front view (Fig. 7-3).

This view shows the shape of the front surface, its length and height. The width of the block does not show in the front view so a second view is necessary.

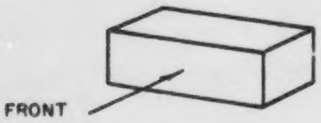


Fig. 7-3 Front view

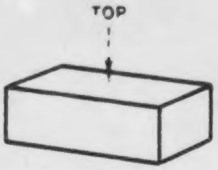


Fig. 7-4 Top view

The upper rectangle in the working drawing (Fig. 7-2) represents the top of the block. It shows the surface of the block which is seen from a point directly above it (Fig. 7-4) and is called a top view. This view shows the shape of the top surface, its length and width. Inasmuch as both views show the length of the block, they are drawn in line with each other with the top view directly above the front view.

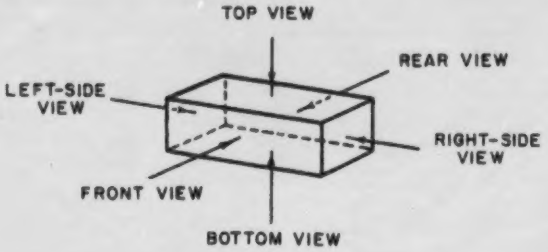

TOP VIEW
REAR VIEW
LEFT-SIDE VIEW
RIGHT-SIDE VIEW
FRONT VIEW
BOTTOM VIEW

Fig. 7-5 Six principal views

Actually it is possible to draw six principal views of any object. These views are seen by looking at the object from six different points of view as illustrated in Fig. 7-5.

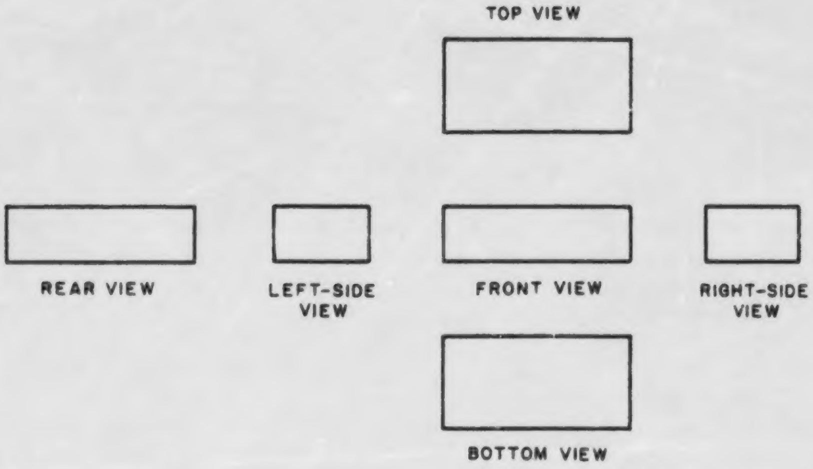

TOP VIEW
REAR VIEW
LEFT-SIDE VIEW
FRONT VIEW
RIGHT-SIDE VIEW
BOTTOM VIEW

Fig. 7-6 Arrangement of six principal views

In working drawings, these six views would be arranged as shown in Fig. 7-6. The rear view, if necessary, may be shown in any one of four positions: in line and to the right of the right-side view, to the left of the left-side view, above the top view, or below the bottom view. However, a draftsman draws only those views necessary to adequately describe the shape of the object. For some objects such as washers, gaskets and simple cylindrical parts, only one view may be necessary.

ORTHOGRAPHIC PROJECTION

The surface of a sheet of drawing paper is a plane with two dimensions, height and width. The objects that a draftsman is required to represent have three dimensions — height, width and depth. Whether the primary purpose of a drawing is to create a visual picture of an object or to show its shape accurately for manufacturing, the problem of all draftsmen is how to represent a three-dimensional object on a two-dimensional surface. The problem can be explained as a process of projection. In the preceding unit, you learned that a working drawing may have one or more views. In theory, these views are found by a system of projection.

DESCRIPTION OF ORTHOGRAPHIC PROJECTION

For an object to be manufactured, all its features must be shown systematically in their true dimensions and in their relationship to other features of the object. To do this, a number of views of the object are drawn as seen from different angles. The number of views and the angle of viewing are determined by the rules of orthographic projection. Imagine that a projection plane is placed in front of an object and parallel to one of its faces. If an observer stands at an infinite distance from the object and views it through the plane, his sight lines will be perpendicular to the plane at all points. The sightlines, or projectors, all intersect the projection plane at the same angle (90°) and all the projectors are parallel to each other. Theoretically, a projector occurs whenever two lines intersect or a line changes direction. If every point is marked where the projectors intersect the picture plane, the points on the picture plane will have the same relationship to each other as the points on the parallel face of the object. In orthographic projection, only those lines and surfaces that are parallel to the picture plane project in their true length and shape.

In all cases, a projection plane is considered to be between the viewer and the object. A draftsman should think of himself as viewing the object through a transparent plane of projection. There are 6 principal planes of projection corresponding to the 6 principal views. In orthographic projection, the planes of projection are between the observer and the object. Placed in their proper relationship to each other, the planes of projection form a transparent box (Fig. 7-7) and the object being examined appears suspended within. The object should be oriented so that its most characteristic shape is parallel to the frontal plane and will project in the front view. One or two related views are necessary to describe the shape of an object satisfactorily. Related views are perpendicular to each other and share a common dimension. For example, front and top views are related and width is the common dimension.

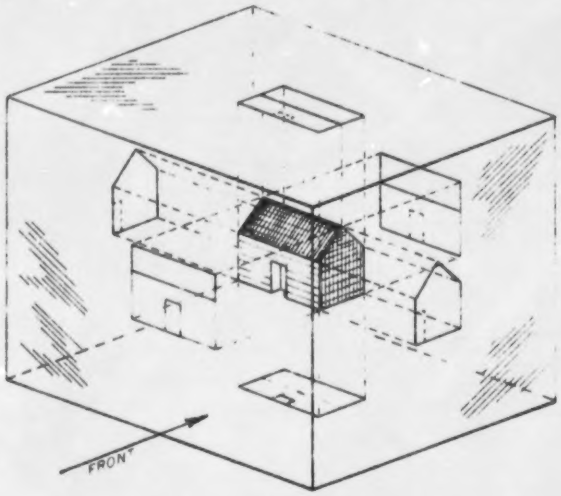


Fig. 7-7

Front, top and right-side views usually are adequate for actual drawing practice. The three other principal views — left-side, rear and bottom — are used only to meet a particular need.

The intersections of adjacent projection planes are represented by lines known as reference, or folding, lines. The common dimension of two related views can be projected along the surface of the projection planes by extending perpendiculars to the reference lines. For example, width is extended between front and top views by constructing perpendiculars to the horizontal reference line. When considering the problem of representing all the projection planes in the plane of the paper, the reference lines should be thought of as hinge connections.

The vertical plane is considered as in the plane of the paper. To arrange the other planes on the surface of the drawing sheet, they must be revolved around their imaginary hinges, as shown in Fig. 7-8, until they are in the same plane as the front view. Fig. 7-9 shows the standard arrangement for views obtained by orthographic projection. Top, bottom, right-side and left-side views are hinged to the 4 sides of the front view. The rear view is revolved as if attached to the right-side view. Note that the front, top and bottom views are aligned vertically; the front, right-side, left-side and rear views are aligned horizontally. In all drafting, the positions of the principal views relative to each other are as shown in Fig. 7-9. When viewing an object one plane at a time, it is customary to represent all edges and intersections whether or not they can be seen from the viewing position. The location of these hidden details is shown by dotted lines called hidden lines. When a hidden line coincides with an object line, or outline, the hidden line is not drawn.

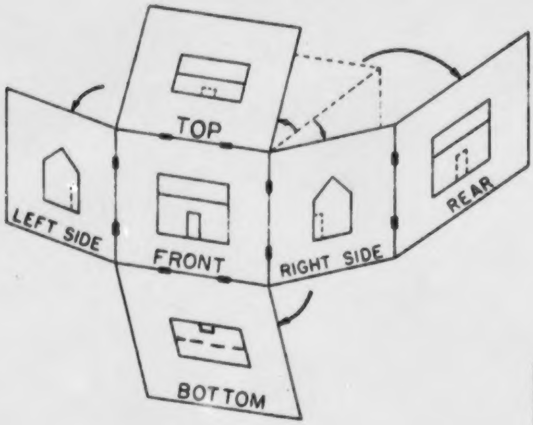


Fig. 7-8

—▬—▬— Folding lines

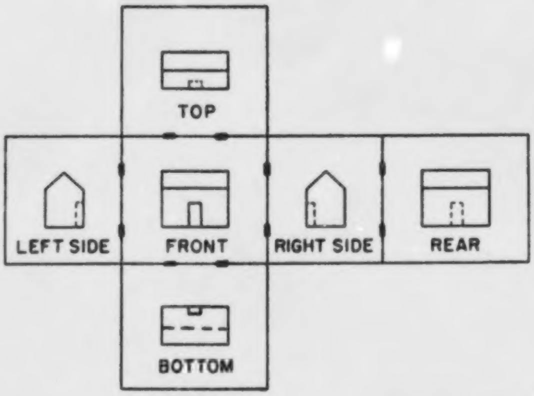


Fig. 7-9

The projection on the vertical plane is called the front view, vertical projection, or front elevation. On the horizontal plane, the projection is called the top view, horizontal projection, or plan. The projection on the profile plane is called the side view, profile projection, side elevation, or end elevation. The last title given in each series is used for describing views of buildings and other structures.

The three views usually selected to describe an object are the front, top and right-side views. The left-side view may be substituted for the right-side view if it presents fewer hidden lines. Front, right-side and bottom are sometimes combined. A 4-projection arrangement of front, top, right-side and rear views is required to present the rear view in standard arrangement. Note that all these combinations include the front view because it is considered to be in the plane of the paper.

PROJECTION LINES

Ordinarily, projection lines are used by draftsmen and designers to establish the relationship of lines and surfaces in one view with corresponding points in other views. Projection lines do not appear on finished drawings except where a part is complicated and it becomes necessary to show how certain details on a drawing are obtained. Projection lines (Fig. 7-10) are fine, unbroken lines projected from a point in one view to locate the same point in another view.

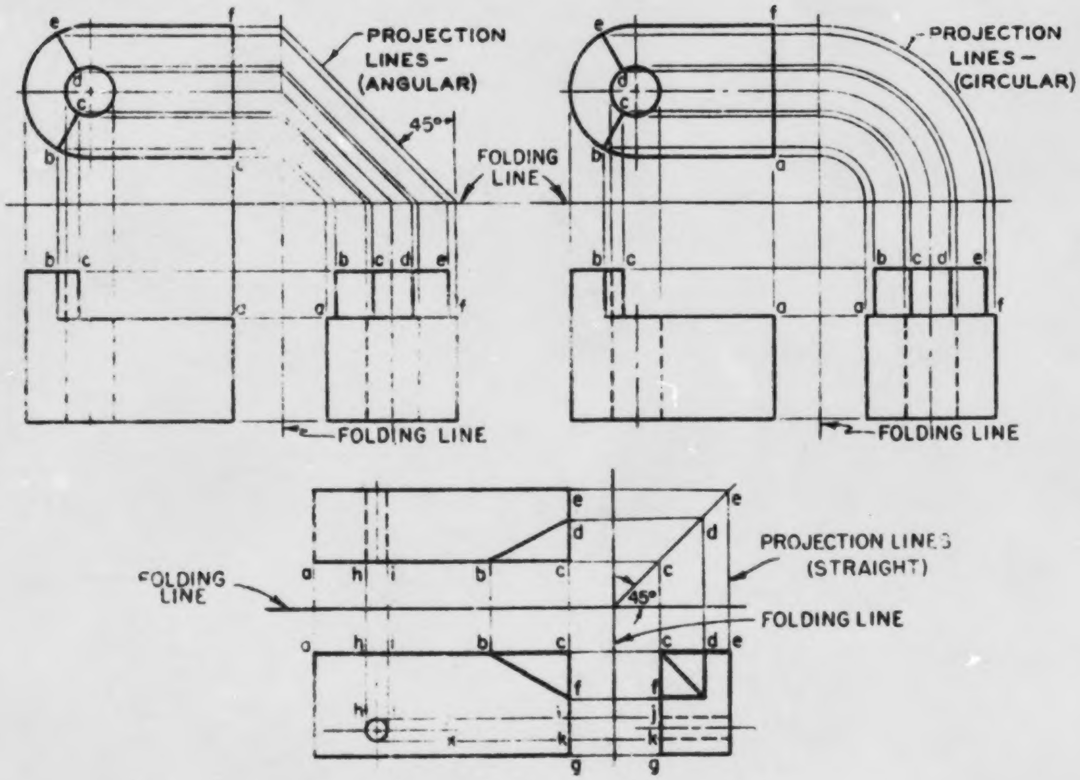

PROJECTION LINES - (ANGULAR)
45°
FOLDING LINE
FOLDING LINE
PROJECTION LINES - (CIRCULAR)
FOLDING LINE
PROJECTION LINES (STRAIGHT)
FOLDING LINE
FOLDING LINE
45°
a
b
c
d
e
f
g
h
i
j
k

Fig. 7-10 Application of projection lines

SELECTION OF VIEWS

In orthographic drawing, objects will be represented by the least number of views that will describe their shape accurately and permit complete dimensioning. Certain fundamental principles will assist a beginner in selecting views.

The view of an object that shows its most characteristic shape should be selected as the front view. Objects are composed of geometric shapes, either singly or in combination. Cylinders, spheres, prisms, cubes, pyramids and cones are examples of geometric shapes, Fig. 7-11. The number of views required to represent an object adequately is determined largely by the kind and number of shapes of which the object is composed.

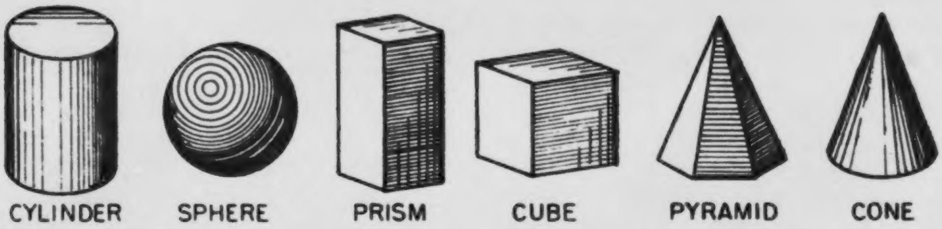


Fig. 7-11

SINGLE-VIEW DRAWINGS

Simple cylindrical pieces can be shown resting on their sides with the axis as a centerline. If the piece is complicated by several holes or slots that cannot be shown easily in one view, additional views are added. A single view of a cylinder is called a longitudinal, or profile view. The third dimension is described by a note. Diameters must be identified by a descriptive note or abbreviation which should follow the numerical dimension and be connected to the proper part with an arrow-type leader. The abbreviation for diameter is dia. A cube may be shown in one view. The abbreviation, sq., for square, follows the dimension to distinguish the cube from a cylinder because both look the same in a profile view. Thin objects of uniform thickness, such as shims, gaskets and plates, also may be shown by one view with a dimensional note giving the thickness.

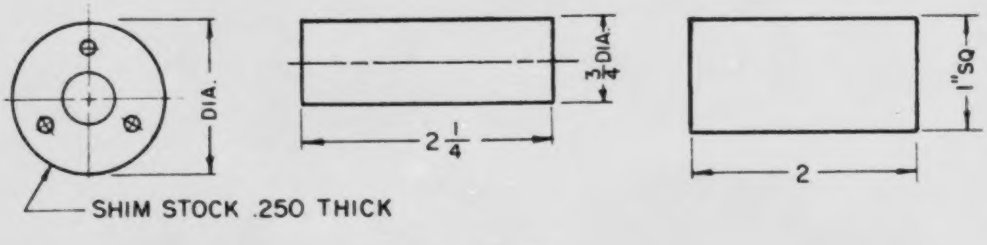


Fig. 7-12

TWO-VIEW DRAWINGS

Two-view drawings may be arranged as any two adjacent views in the relation shown when the glass box is revolved into the plane of the paper. When space is limited, it is permissible to represent symmetrical objects by half views extended slightly beyond the centerline of symmetry and terminate with a breakline. If the adjacent view is an exterior view, the new half of the symmetrical view will be drawn. If the adjacent view is a full or half section, the far half of the symmetrical view will be drawn.

THREE-VIEW DRAWINGS

The majority of objects represented in orthographic drawings are irregularly shaped and require three views. Complicated objects may require more. If an important face of an object is not parallel to any of the principal planes of projection, either a primary auxiliary or secondary auxiliary view must be used to show its true shape.

The glass box, Fig. 7-7, when opened and revolved into the plane of the paper, gives an idea of the proper spacing between views. Because all of the projection planes are considered equal in size, and the object itself is thought of as being suspended in the center of the enclosed space, related views are always spaced between views on a standard 11″ × 17″ sheet in from 1″ to 2″. The remaining problem in representing a three-dimensional object is to balance the spacing of the views within the working area of the drawing sheet.

ASSIGNMENT

1. What view should be selected which will distinguish the shape in detail?
2. What determines the number of views required?
3. Give the reasons for a single-view drawing, two-view drawing and a three-view drawing.
4. Why are projection lines used when developing a drawing?
5. What views are usually selected to describe an object?
6. Sketch the six principal planes of projections.
7. Describe the working drawing as drawn by a draftsman.
8. Define the meaning of an orthographic drawing.
9. Objects are composed of what shapes singly or in combination?
10. When would a left-side view be substituted for a right-side view?
11. In each three-view drawing of Fig. 7-13 some lines have been intentionally omitted. Read the drawings and supply the missing lines.

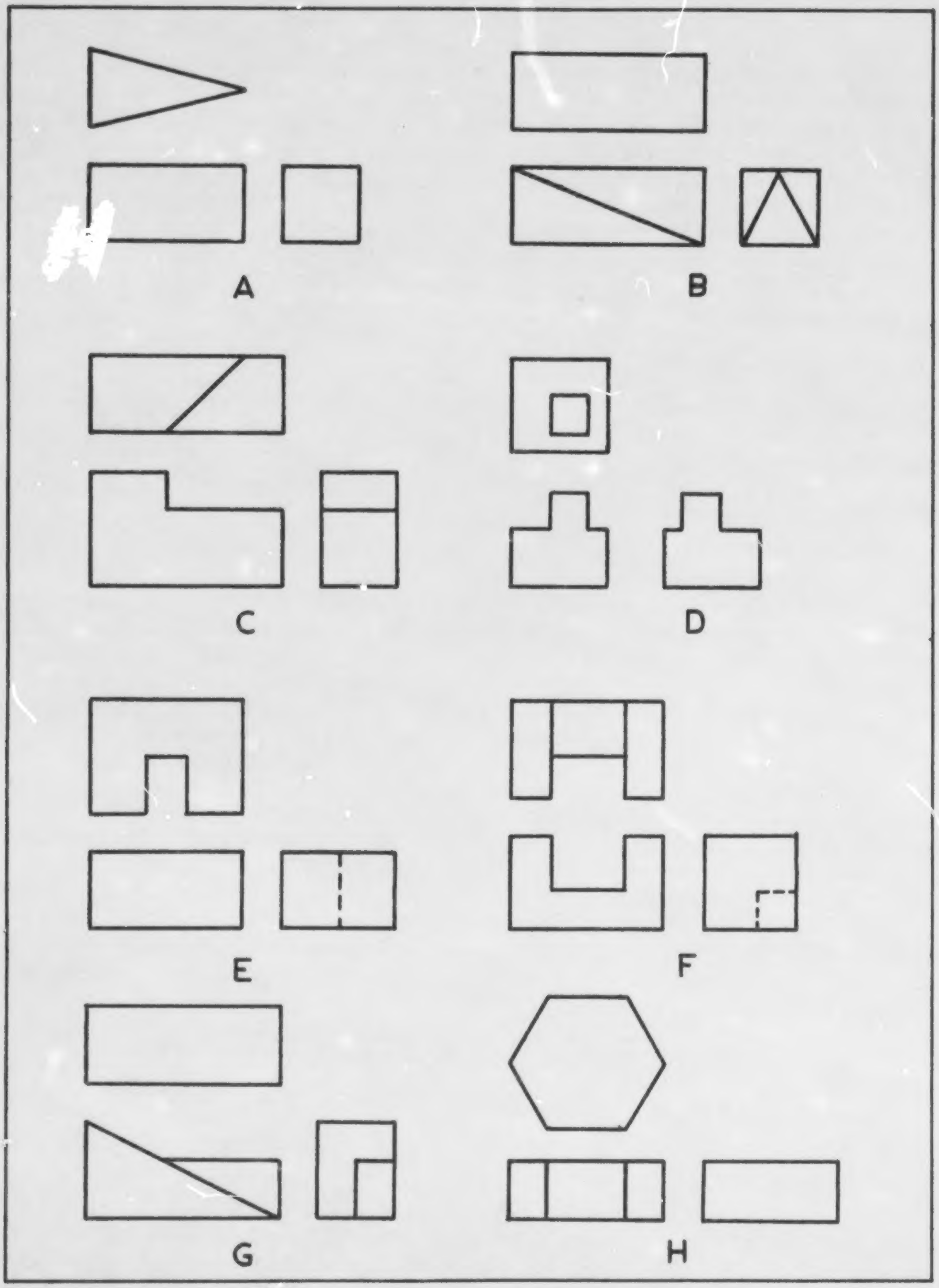


Fig. 7- 13

Unit 8 FREEHAND SKETCHING

There are many occasions when a drawing can be presented more conveniently in a freehand sketch than in a drawing prepared with instruments. A freehand drawing is the most suitable way for designers to show a draftsman what is wanted in a finished drawing. A technical sketch is a freehand orthographic drawing. A pictorial sketch is a freehand isometric drawing. The principles of orthographic projection and isometric drawings are the same whether a drawing is executed freehand or with instruments. The fundamentals presented in this section will provide the beginner with a satisfactory technique for preparing accurate, legible freehand sketches.

PAPER FOR SKETCHING

Cross section paper is an aid in drawing straight lines and in holding to a reasonably accurate scale. A pad of 8 1/2″ × 11″ cross section paper composed of 1/4″ squares or 10 squares to the inch, is recommended.

PENCILS

The pencils used for sketching should be of good quality. A grade of hardness of F, H, or HB is best suited to this form of drawing. This grade permits a good dark line to be drawn without digging into the paper. Erasures can be made more easily when lines are not deeply cut into the sheet. In addition, this grade of pencil is sufficiently hard so that the lines which are drawn are not easily smudged. It is possible with this pencil to get the varying weights of lines which are necessary.

For best results, the pencil should be sharpened to a long, conical point, with at least 1/4″ of lead extending beyond the wood. Many mechanical sharpeners do a fine job of preparing the pencil point. However, since a sharpener is not always available, most men use a pad of fine sandpaper to bring the pencil to a sharp point. The illustration indicates how the pencil should be rotated as it is pulled across the sandpaper to produce a good point. Failure to rotate the pencil will cause flat surfaces on the lead which are undesirable for this type of drawing. It is also good practice to wipe away the excess powdered lead which clings to the point after sharpening. Leaving the powder on the point will cause smudges on the paper.

An artgum eraser should be used to remove unwanted lines and to keep a drawing clean. (See Unit 1, page 6.)

MEASURING EQUIPMENT

The choice of measuring equipment is determined by the size of the object or part to be sketched. For most objects or parts, a 6″ steel machinists' scale is adequate.

STRAIGHT LINE SKETCHING

Sketches are used in many cases in preference to an instrument drawing because they can be made so quickly and do not require many tools. However, in order to be useful, the sketch should be carefully and neatly drawn. The lines should be clean and straight. The comparative weights of the different types of lines should be the same as in an instrument drawing. The information contained in the sketch should be complete. Most important, the proportions of the object to be sketched should be reasonably accurate.

Most of us can draw a short line freehand and it will appear to be straight. Long lines, however, present a difficulty. No matter how we try, a long line drawn with a single stroke will appear wavy and bent. Repeated practice will improve the quality of line work. There are several tricks that the beginner can use to help in developing proficiency in drawing long lines. One of the simpler tricks is to use a series of dots along the path of the line which he wishes to draw. To illustrate, let us attempt to draw a line freehand about 6″ long. If we try it in one stroke, the line will almost certainly be wavy. Now, instead of sketching the entire line, let us lay out a row of dots about 1″ apart, as shown in Fig. 8-1.

Fig. 8-1

If we now hold the paper up and sight along this row of dots, any dot that is out of line shows up immediately and can easily be shifted so that all the dots are in line. It is now a relatively simple job to draw a light line connecting each of the dots. As a final step, we should go over the entire line with a single stroke, making it the weight we desire. With additional practice, the beginner will be able to widen the distance between dots and, eventually, eliminate them entirely.

Horizontal lines are best drawn from left to right as indicated on the sketch. These lines should be drawn with a forearm rather than a wrist movement. While pivoting from the wrist may be a somewhat easier movement for the beginner, it will cause a curve when drawing longer lines. When a series of lines are to be drawn, it is good practice to sketch all of them lightly first. When you are sure that your sketch is correct, the lines can all be darkened at the one time. This practice eliminates much erasing and serves to keep the sketch clean.

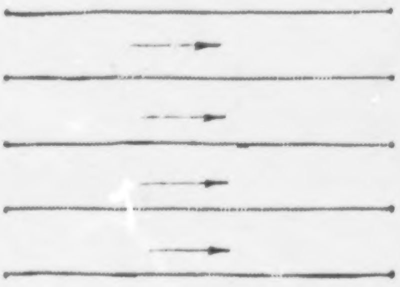


Fig. 8-2

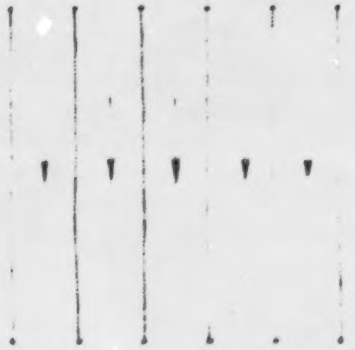


Fig. 8-3

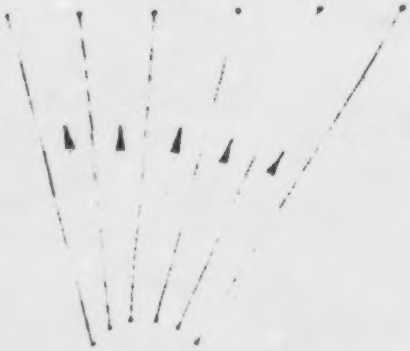


Fig. 8-4

Vertical lines, as shown in Fig. 8-3, are best drawn from the top down. As in drawing horizontal lines, the forearm should be used as a pivot point. Long, vertical lines can be drawn by using the row of dots as an aid. To draw lines parallel as they are shown here is a difficult job for the beginner Many men use a piece of paper as a ruler to mark off equal distances at each end of a line. A line sketched through these two points will be parallel to the first line. Again, repeated practice will increase the sketcher's proficiency to the point where he will not have to rely on any aids.

Sloping lines can be drawn in the same manner as horizontal or vertical lines. One of the advantages of freehand sketching is that the paper is not taped or tacked down in a stationary position, and the sketcher is free to turn the paper in any direction. This freedom of movement makes it simpler to draw lines that might otherwise be in an awkward position.

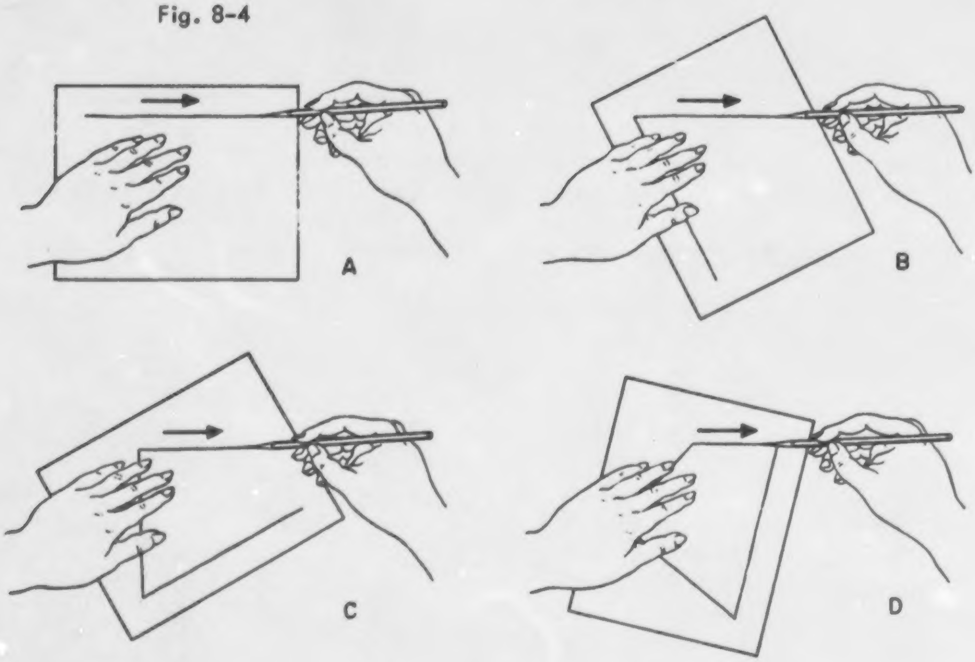


Fig. 8-5 Sketching straight lines

SKETCHING CIRCLES, ARCS AND IRREGULAR SHAPES

One of the more difficult operations of freehand sketching is to construct a circle or a part of a circle. There are, however, several so-called tricks of the trade which can be used to simplify this operation.

One of the prime causes of poorly sketched circles on the part of the novice is the fact that he tries to draw the entire circle by sight and in one stroke. Like all of the other drawing details, a circle or an arc should be carefully laid out before it is drawn.

Note that the circle in Fig. 8-6 bears some geometric resemblance to a square. Its length and height are the same size as are those of the square. If the square were circumscribed about the circle as shown, it can readily be seen that the two figures are tangent to each other at four points, each point being the intersection of the centerline of the circle and the midpoint of one of the sides of the square.

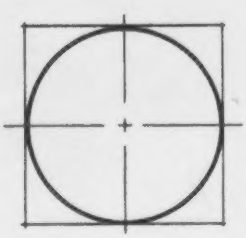


Fig. 8-6

Since the square is relatively easy to sketch, it can be used as the beginning point for sketching the circle. The procedure would be:

1. Sketch a square of the same size as the diameter of the required circle, Fig. 8-7.
2. Mark off the center point of each of the four sides (A, B, C and D).
3. Sketch lines A-B and C-D. These lines represent the vertical and horizontal centerlines of the circle. They divide the square into four smaller squares.

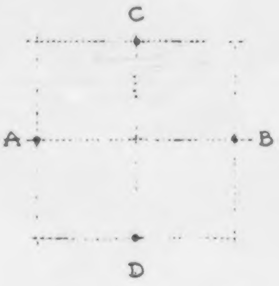


Fig. 8-7

4. In each of the four squares, sketch an arc that is tangent to two sides of the square, Fig. 8-8. Sketch these arcs with light, feathered strokes as shown.
5. When the four separate arcs have been sketched roughly, make any necessary sketching strokes to blend them completely into one smooth curve.
6. Go over the outline of the circle with a single stroke so that the circle is drawn to the same weight of line as the rest of the sketch.

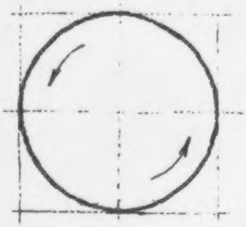
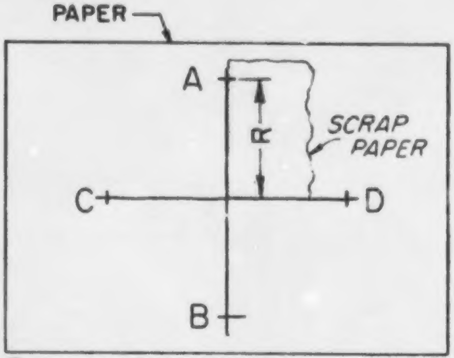


Fig. 8-8

SKETCHING LARGE DIAMETER CIRCLES OR ARCS

The method outlined on the previous page can be of invaluable assistance to the beginner for sketching small diameter circles. Instead of working from a single reference point, the center of the circle, he has four such points to help him in sketching a smooth outline. For circles of large diameter, however, four reference points are not sufficient to produce a smooth curve. The resultant circle, drawn with only four reference points, will usually consist of four flattened-out or otherwise distorted arcs which will not produce the desired appearance.

The construction of a circle of fairly large diameter requires the use of additional reference points which may be obtained in the following manner:

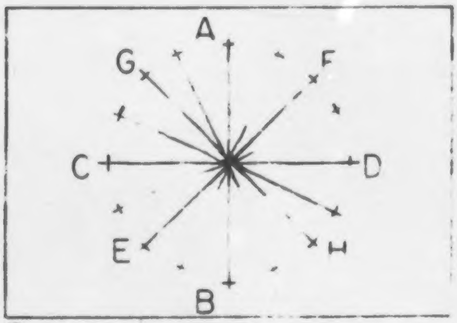


① ESTABLISH POINTS

Fig. 8-9

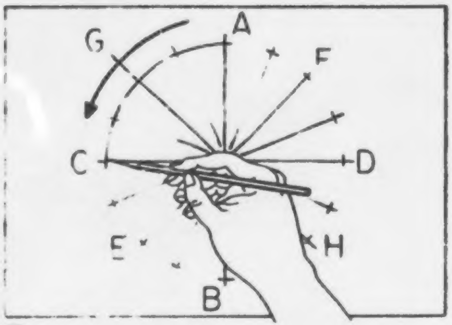
1. Lay out centerlines A-B and C-D as shown in Fig. 8-9.
2. Sketch in lines E-F and G-H (Fig. 8-10). These diagonal lines should approximately bisect each of the four right angles which are formed by the two centerlines. Then sketch in additional diagonal lines to subdivide again all of the angles as shown. (Note: The larger the diameter of the circle, the more diagonal lines will be needed to produce a smoothly curved circle or arc.)

Mark off the required radius from the center on each of the diagonal lines. To insure accuracy, the distance should be marked off on the edge of a sheet of paper and then transfered to each of the construction lines of the sketch.



② ADD RADIAL LINES, ESTABLISH POINTS

Fig. 8-10

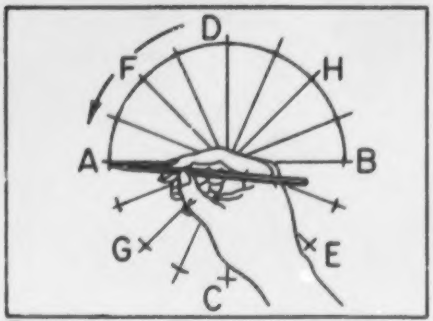


③ DRAW FIRST ARC

Fig. 8-11

3. Sketch in the circle with short strokes so that it passes through each of the reference points. Up to this point, all of the construction lines should be drawn very light so that they will not interfere with the finished outlines. (Fig. 8-11)

4. Complete the circle with a solid, single-stroke line so that it blends with the rest of the sketch. (Fig. 8-12. Note that paper has been rotated.)



④ DRAW SECOND ARC

Fig. 8-12

SKETCHING AN IRREGULAR SHAPE

Sketching an irregularly-shaped object requires the use of many reference points. For such sketches, the use of cross-hatched or graph paper as shown below greatly simplifies the drawing. Fig. 8-13 shows the steps to follow in sketching an object or a workpiece with a nonuniform or irregular shape.

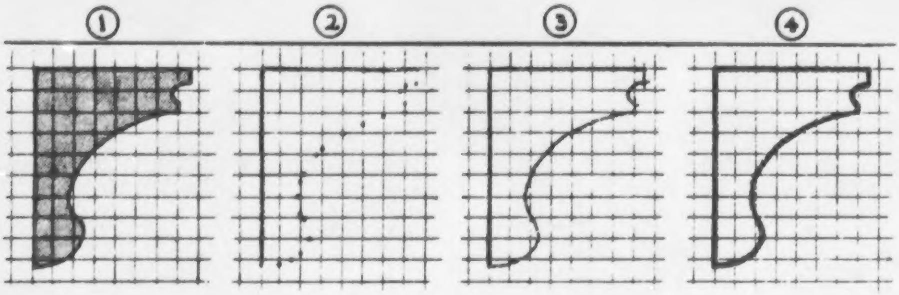


Fig. 8-13

1. Lay out a series of equally spaced vertical and horizontal lines across the view to be sketched. The space between the lines will depend on the complexity of the shape. For the most accurate reproduction, the lines should be fairly close together since this condition will provide the greater number of reference points.

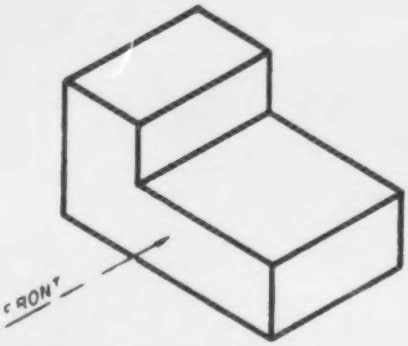
2. On a blank sheet of cross-hatched paper which has the same size squares as the original, plot each of the reference points as it appears on the original.

3. Sketch in lightly the irregular shape so that it passes through each of the reference points.

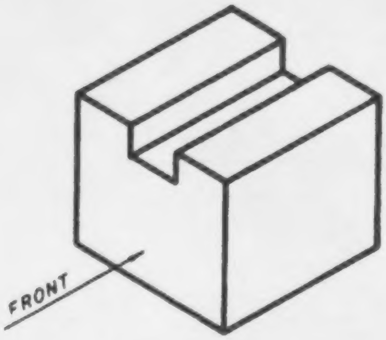
4. Darken the outline so that it blends in with the other lines of the sketch.

ASSIGNMENT

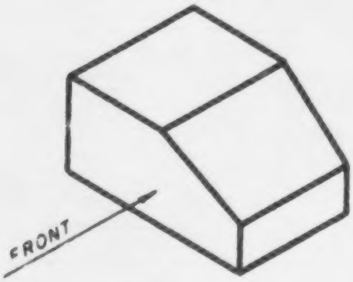
Redraw the following orthographic sketches, Problems 8-1 through 8-15.



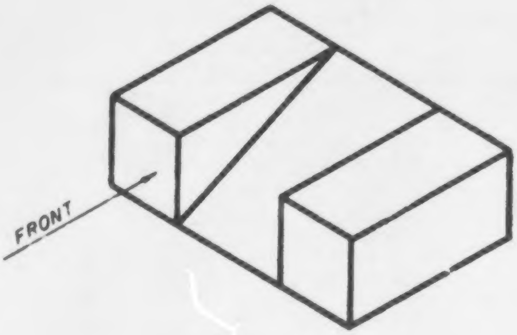
PROBLEM 8-1



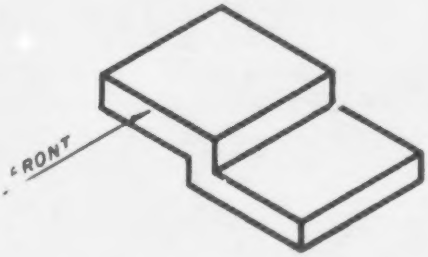
PROBLEM 8-2



PROBLEM 8-3

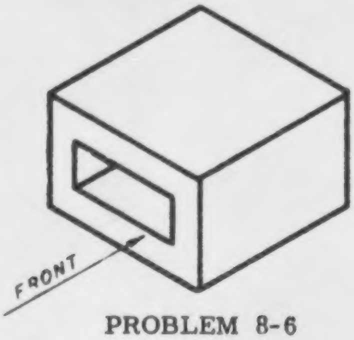


PROBLEM 8-4

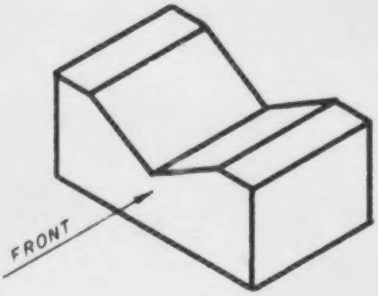


PROBLEM 8-5

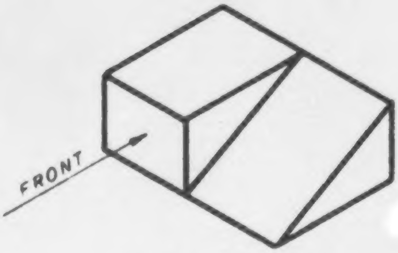
Sketch the front, top, and right side views.



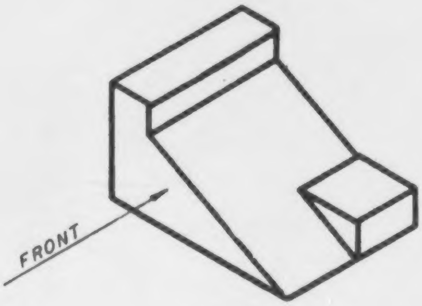
PROBLEM 8-6



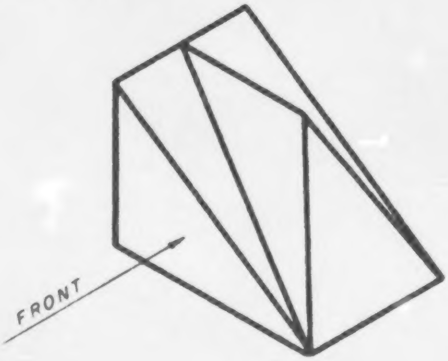
PROBLEM 8-7



PROBLEM 8-8

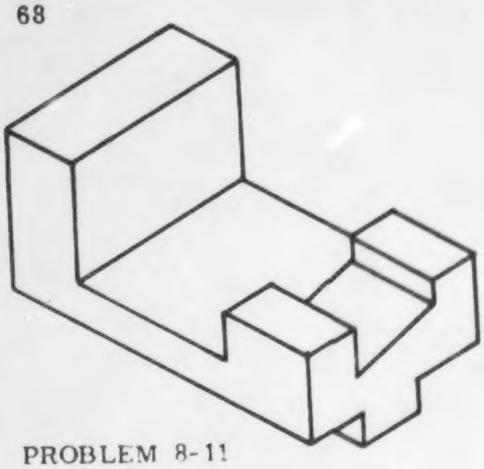


PROBLEM 8-9

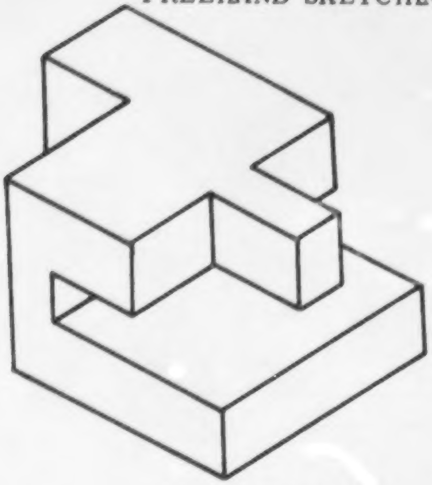


PROBLEM 8-10

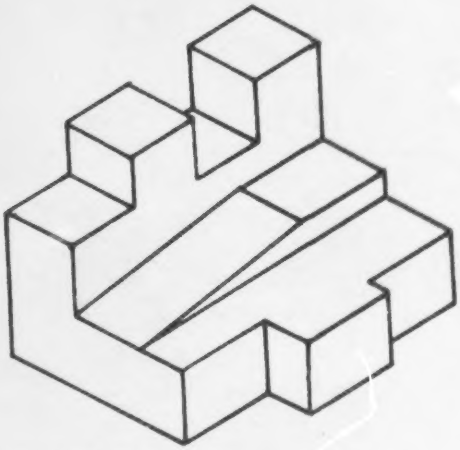
Sketch the front, top, and right side views.



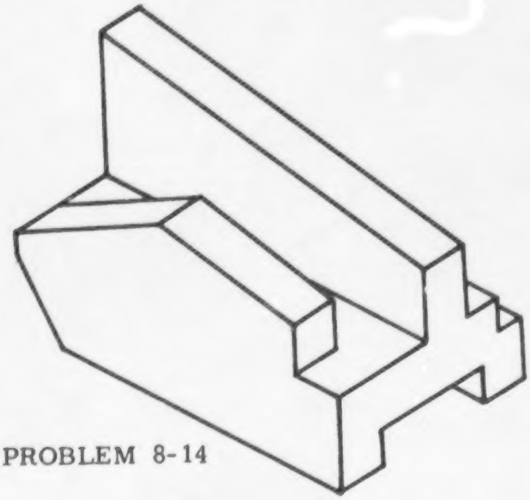
PROBLEM 8-11



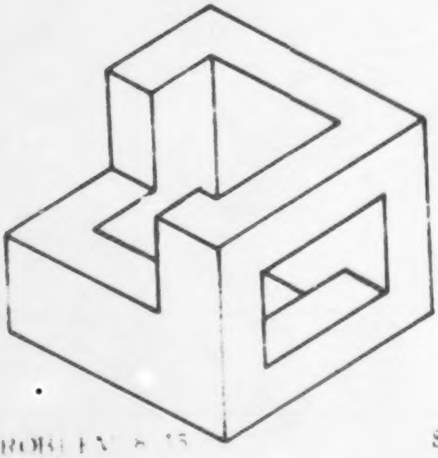
PROBLEM 8-12



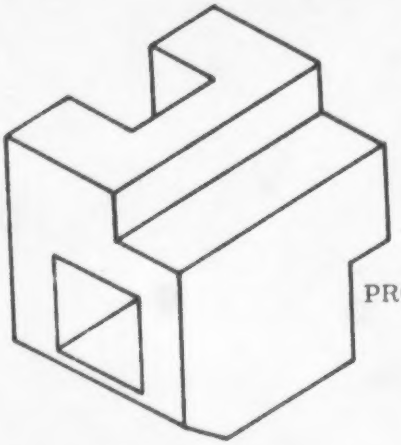
PROBLEM 8-13



PROBLEM 8-14

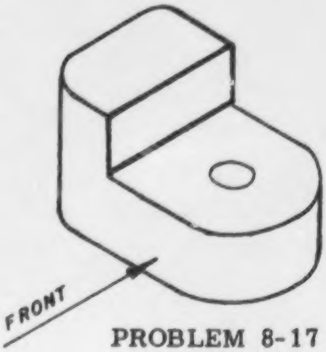


PROBLEM 8-15

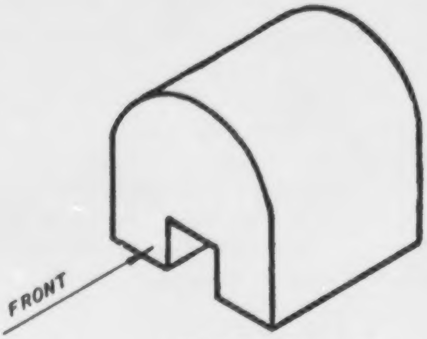


PROBLEM 8-16

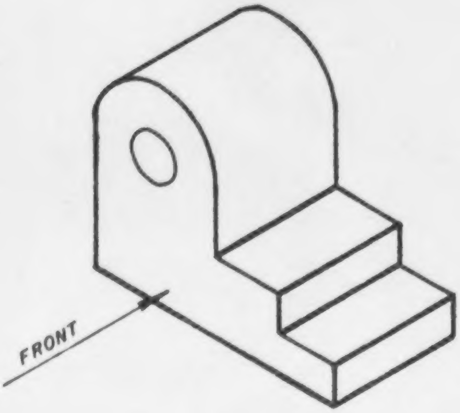
Sketch the front, top, and right side views.



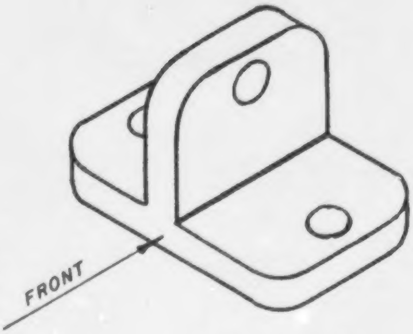
PROBLEM 8-17



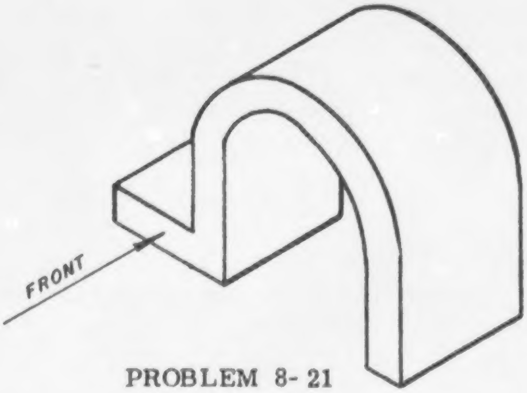
PROBLEM 8-18



PROBLEM 8-19



PROBLEM 8-20



PROBLEM 8- 21

Sketch the front, top, and right side views.

SECTION III *DIMENSIONING AND NOTES*

Unit 9 DIMENSIONING AND NOTES

The discussion of technical drawings so far has covered only shape descriptions. To manufacture an object in accordance with a designer's specification, a mechanic or craftsman needs more information than that furnished by the scale drawings of its shape. The systematic description of shape must be accomplished by a systematic description of size. Height, width and length of the object, size and location of its features, plus other important numerical details, must be stated clearly. The system of lines, symbols, numerals and dimensional notes furnishing this information is called dimensioning. Dimensions are numerical values, expressed in units of measure, that define the geometrical characteristics of an object and establish its location.

NUMERALS AND LETTERS

All numerals used for dimensioning and all lettering used for dimensional notes will conform to the requirements as presented. All figures and numerals are to be vertical and freehand with very light guide lines for whole numbers, letters and fractions, (Figs. 9-1 and 9-2).

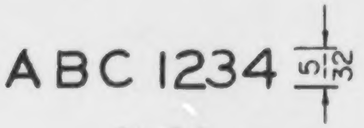


Fig. 9-1

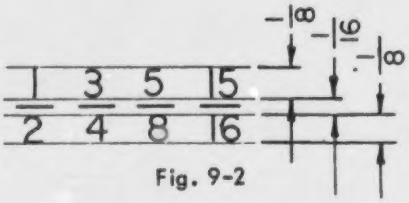


Fig. 9-2

ARROWHEADS

Arrowheads are drawn freehand with two concave strokes made in the direction of the point (Fig. 9-3). The length of an arrowhead will be approximately three times its width at the base and varied from 5/32" in small drawings to 3/16" in larger drawings (Fig. 9-4). Arrowheads will be drawn the same size throughout a drawing except in restricted spaces where they may be smaller.

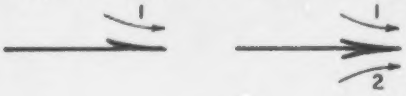


Fig. 9-3

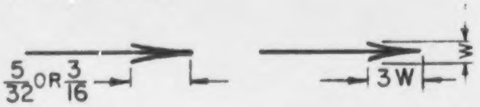


Fig. 9-4

LOCATION OF DIMENSION VALUES

The machine drafting practice locates dimension values in the center of the dimension line (Fig. 9 -5), while the structural drafting practice locates dimension values above the dimension line (Fig. 9-6).

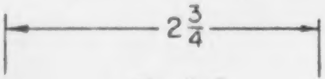


Fig. 9-5

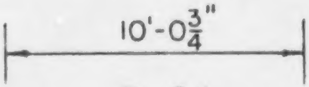


Fig. 9-6

UNITS OF MEASURE

The unit of measurement in machine drafting as recommended by most industries will be the inch values up to 72 inches and beyond this value, feet and inch values are used. When the dimension is in units of inches only, inch marks will be omitted.

In structural drafting there is usually a combination of units of measurement and unit symbols are used. Dimensions are hyphened thus: 4′-7″, 6′-0 3/4″ and 5′-0′. On items such as timber and beam sizes, the dimensions are given in inches: 2 × 4, 2 × 6, 4 × 8, 5 × 12, etc.

BASIC PRINCIPLES FOR THE PLACEMENT OF DIMENSIONS

1. Dimensions should not be duplicated nor the same information given in two ways.
2. Dimensions should be given to finished surfaces or important center lines.
3. Dimensions should be given so that the workman will not have to calculate, scale, or assume any dimensions.
4. Dimensions should be added to views in which the shape is best shown.
5. Avoid dimensioning to hidden lines.
6. Place overall dimensions outside the intermediate dimensions.
7. Detail dimensions should "line up" in a continuous line.

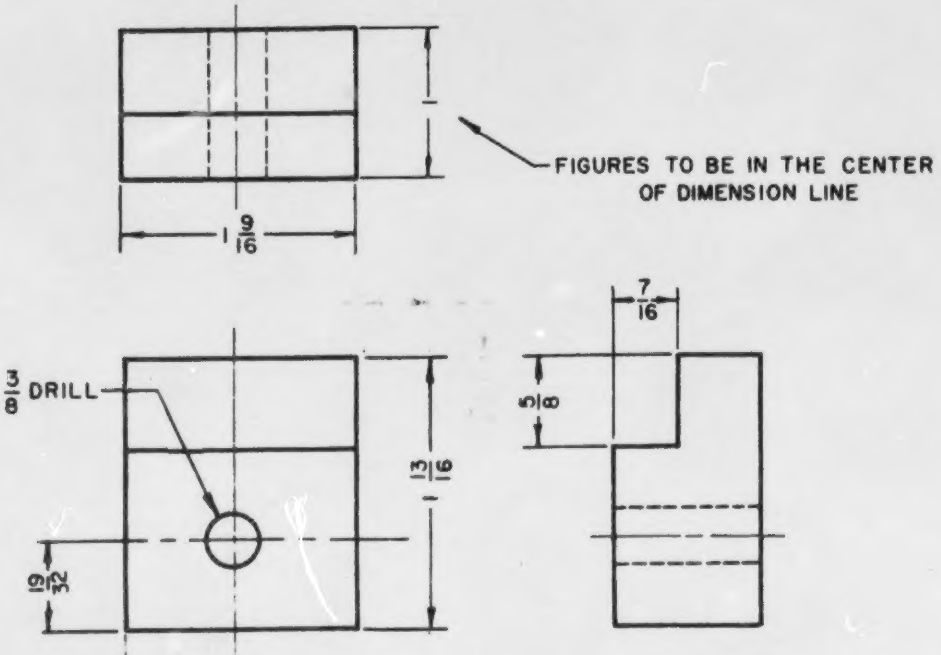


Fig. 9 -7

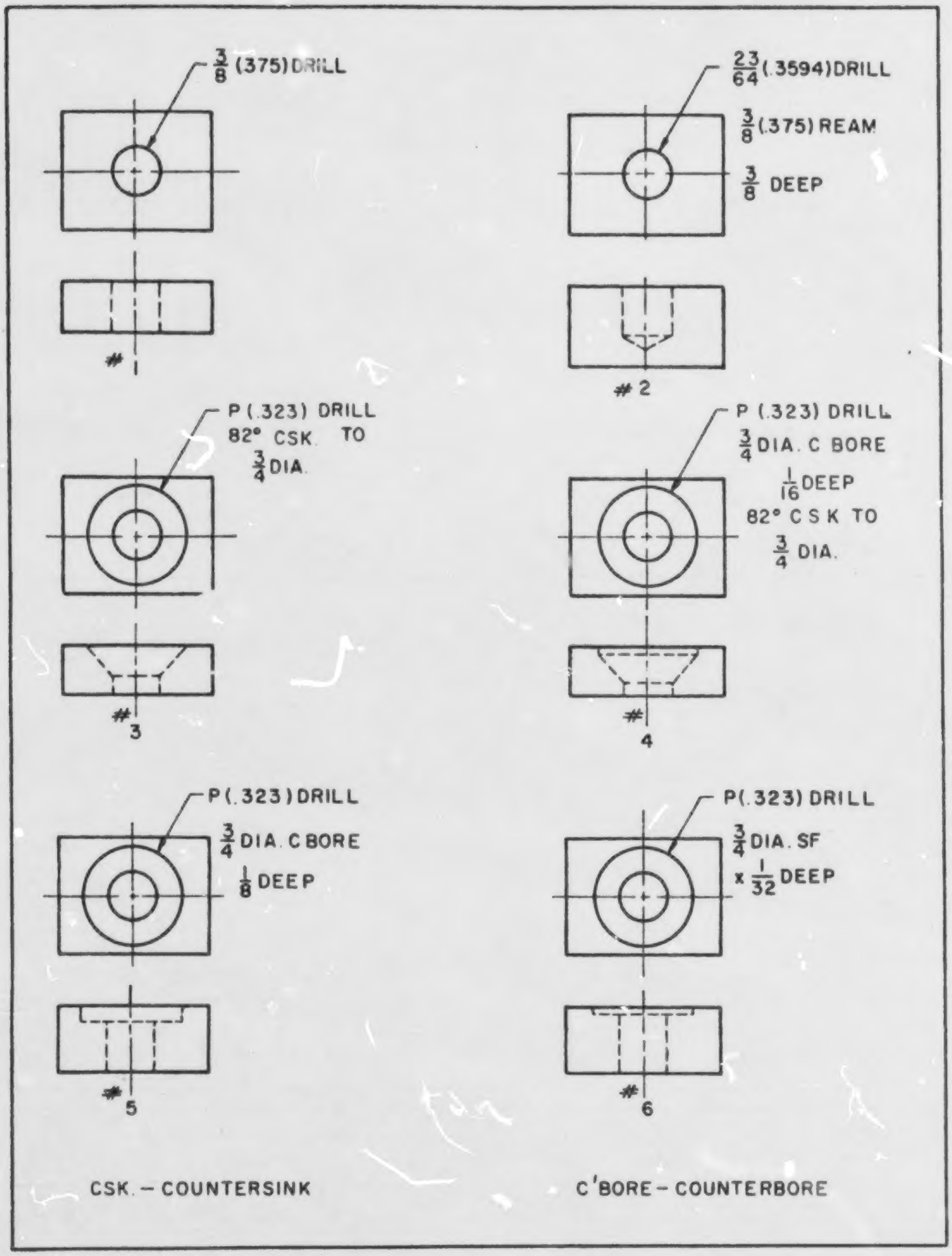

3/8 (375) DRILL
#1
23/64 (.3594) DRILL
3/8 (.375) REAM
3/8 DEEP
#2
P (.323) DRILL
82° CSK. TO
3/4 DIA.
#3
P (.323) DRILL
3/4 DIA. C BORE
1/16 DEEP
82° C S K TO
3/4 DIA.
#4
P(.323) DRILL
3/4 DIA. C BORE
1/8 DEEP
#5
P(.323) DRILL
3/4 DIA. SF
x 1/32 DEEP
#6
CSK. – COUNTERSINK
C'BORE – COUNTERBORE

Fig. 9 -8 Types of holes with appropriate notations

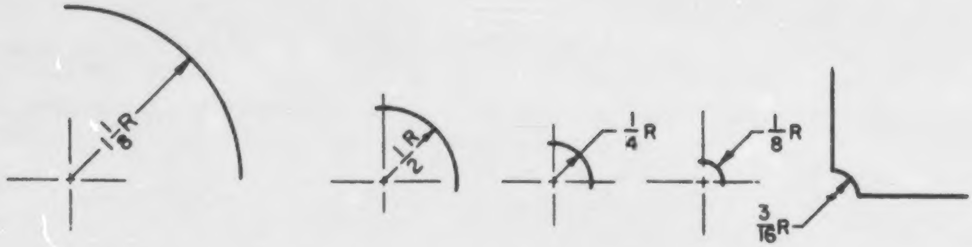


Fig. 9 -9 Dimensioning arcs

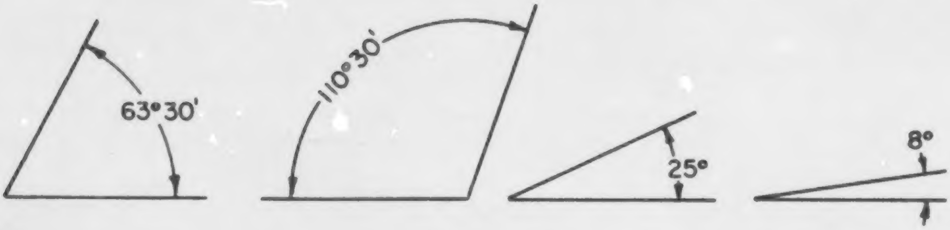


Fig. 9 -10 Dimensioning angles

ASSIGNMENT

1. What is the proper size of an arrowhead on a drawing?
2. In what direction should one be able to read all dimensions?
3. Dimension figures and letters should be held to what height?
4. When should inch marks be omitted from dimensions?
5. What is the height of fractions and the length of arrowheads?
6. At what distance from the object should the extension lines start?
7. What are the differences between structural and mechanical dimensioning?
8. Why should dimensions be placed outside of the view?
9. Show in a sketch the dimensioning of arcs and angles.
10. Why should dimensions be given to a finished surface?

Unit 10 FRACTIONAL AND DECIMAL DIMENSIONING SYSTEMS

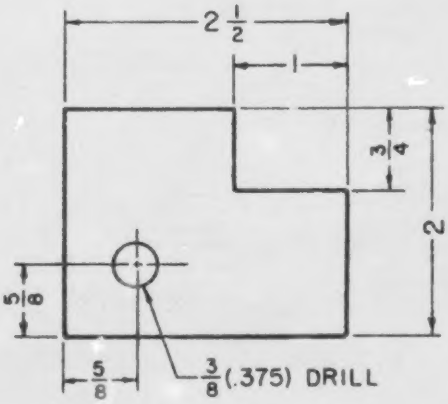
The fractional system is composed of fractions in increments from 1/64 to 63/64. The system is used in the field of architectural and civil engineering when close accuracy is unimportant. At times, in the field of manufacturing, fractions are used in dimensioning where liberal tolerances are acceptable.

The decimal-fraction system is used in the field of machine drafting for dimensions smaller than 1/64 of an inch, and also for converting a fraction to a decimal in tenths, hundredths, thousandths, ten thousandths, etc., for very close dimensions.

The complete decimal system is a two place decimal for all common fractions such as .01, .02, .03, etc. If greater accuracy is required, three or four place decimals are used, such as .015, .020, .022, etc. The engineer and draftsman must think in terms of tenths, hundredths, thousandths, etc., instead of in common fractions. At present, standard stock materials, tools and commercial items are in the decimal-fraction system and must be converted to a complete decimal system, if possible.

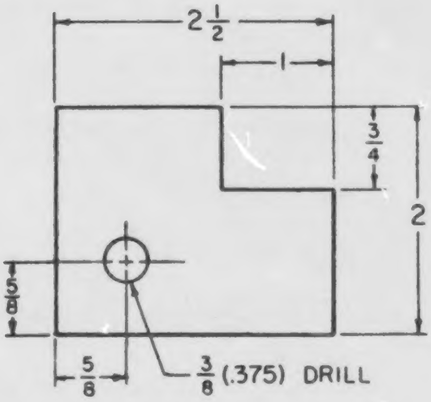
Directional methods for locating dimension figures are the aligned and the undirectional systems. The aligned system is read from the bottom for all horizontal dimensions and from the right side for all vertical dimensions, as in Fig. 10-1 The undirectional system is read from the horizontal (or bottom) position of the drawing (Fig. 10-2).

Notes for both the aligned and undirectional systems are read from the horizontal or bottom position of the drawing.



ALIGNED SYSTEM

Fig. 10-1



UNDIRECTIONAL SYSTEM

Fig. 10-2

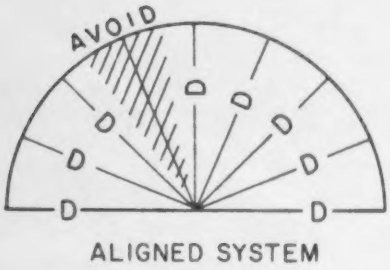

AVOID
D
D
D
D
D
D
D
D
ALIGNED SYSTEM

Fig. 10-3

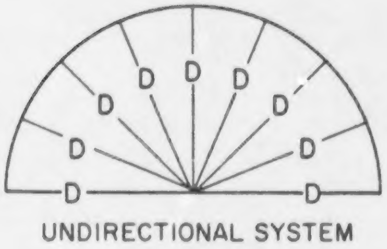

D
D
D
D
D
D
D
D
D
D
D
UNDIRECTIONAL SYSTEM

Fig. 10-4

DIMENSIONING KNURLS

Knurled parts are dimensioned with a note stating the pitch and the kind of knurl. See Fig. 10-5. The pitch of a diamond-shaped knurl is the number of cuts per inch measured parallel to the axis of the part.

- Fine knurling has 33 cuts per inch, or 33 pitch.
- Medium knurling has 21 cuts per inch, or 21 pitch.
- Coarse knurling has 14 cuts per inch, or 14 pitch.

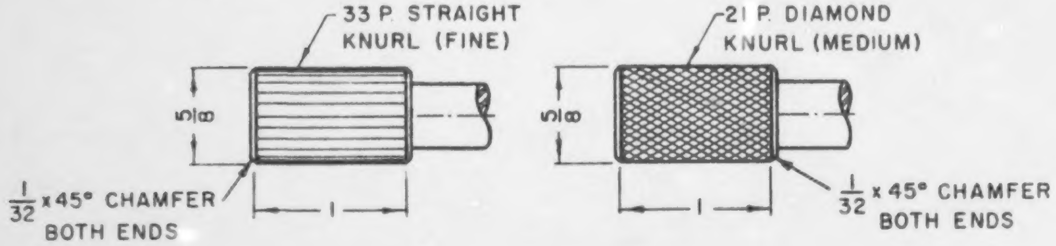

33 P. STRAIGHT KNURL (FINE)
5/8
1/32 x 45° CHAMFER BOTH ENDS
1
21 P. DIAMOND KNURL (MEDIUM)
5/8
1
1/32 x 45° CHAMFER BOTH ENDS

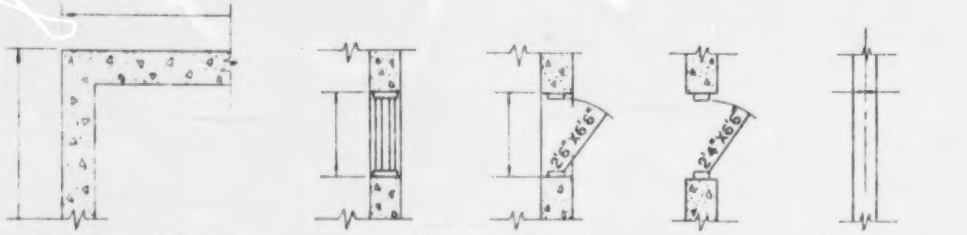
Fig. 10-5

DRAWING KNURLED PARTS

Diamond knurling is represented on drawings with two series of lines sloping in opposite directions. These lines are drawn at 30° to the axis of the part. The lines should be spaced by eye to look well and need not be drawn to the actual pitch. Straight knurling is drawn with straight lines parallel to the axis of the pieces as shown above.

VARIATIONS IN DIMENSIONING PRACTICES

In structural drafting, many variations occur. Examples of variations in dimensioning practices caused by differences in materials and methods of construction are shown in Fig. 10-6. In addition, it presents dimensioning conventions for doors, windows and walls. All dimensioning is applicable to plan views only as shown.



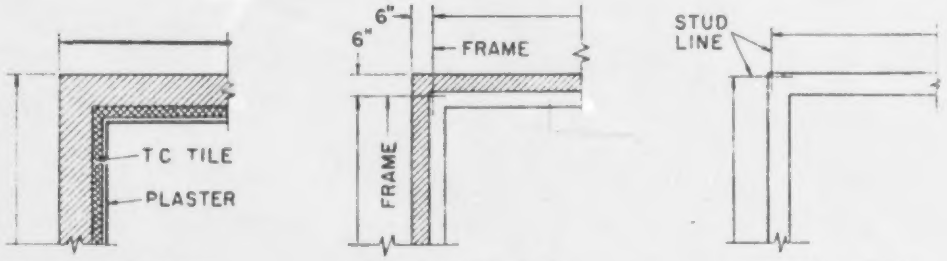
CONCRETE WALL (DIMENSION TO OUTSIDE CORNER)

DOUBLE-HUNG WOOD WINDOW IN MASONRY WALL

EXTERIOR DOOR IN MASONRY WALL

INTERIOR DOOR

INTERIOR WOOD STUD PARTITION (DIMENSION TO ℄ OF PARTITION)



SOLID BRICK WALL (DIMENSION TO OUTSIDE CORNER)

BRICK VENEER WALL (DIMENSION TO WOOD FRAME)

WOOD FRAME (DIMENSION TO STUDS)

Fig. 10-6

DIMENSIONING REQUIREMENTS

- Locate dimension value in the center of dimension.
- Arrowheads to be approximately 3/16″ long.
- Extension lines to extend beyond dimension line by 1/8″
- Dimension line spacing to be in 1/2″ increments, starting at the object.
- Guide lines to be used for all dimensions, notes, title block and bill of materials.
- General notes to be located in upper left-hand corner of drawing.
- Note leader to slope 45°, 60° (or any other angle) but not on the vertical of horizontal lines.

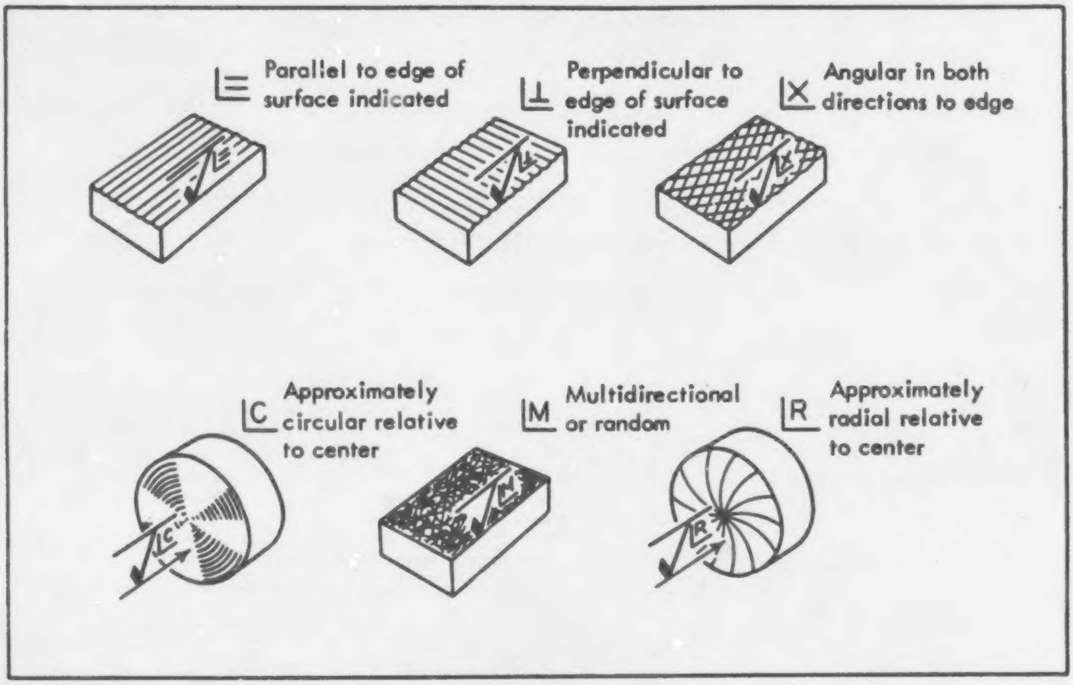
- Use staggered dimensioning when dimensions are above each other.
- Avoid crossing dimension lines.
- Use one system throughout the drawing, on aligned or undirectional dimensioning.
- Dimensions are not to be repeated in each view.
- Dimensions are to be located on the silhouette of the object.
- Continuous dimensions are to be in line.
- Casting and forging dimensions are to be contained within their own fabrication.
- Machine dimensions are to be contained within their own fabrication.
- Dimensions should include an overall measurement.
- Dimensions are to be located from the object side or from a centerline.
- Extension lines and centerlines are not to be connected between views.
- Machine marks to be omitted on machine drawings.
- Use one type of tolerancing on details and assemblies.
- Drawings should scale to within 1/64 of an inch.
- Holes to be located on centerlines.
- Finish marks to be located on edge of surfaces.
- Note to be lettered horizontally and statement to be concise.

ASSIGNMENT

1. Define the fractional system, decimal-fraction system, and complete decimal system and explain their uses in the fields of engineering.
2. How far should the extension lines be extended beyond the dimension line?
3. Where should the general notes be located in the working drawing?
4. When should staggered dimensioning be used and why?
5. Define aligned and undirectional dimensioning.
6. Why should casting, forging and machine dimensioning be contained within their own fabrication?
7. At what angles should the note leaders be sloped?
8. Finish marks are to be located from what surface?
9. Why should guide lines be used for notes, dimensions, title block, etc.?
10. Define the three classes of diamond knurls and list the pitches.
11. Why should a chamfer be made at each end of the knurl?
12. Why should dimensioning be located, if possible, between views?

Unit 11 SURFACE QUALITY FINISHES

Due to production methods and costs in industry today, it is essential to specify the type of finish which is necessary for mating surfaces and those which are only exposed surfaces. Industries have established definite classifications for various degrees of roughness, waviness and direction of tool marks: See Fig. 11-1.


Parallel to edge of surface indicated
Perpendicular to edge of surface indicated
Angular in both directions to edge
Approximately circular relative to center
Multidirectional or random
Approximately radial relative to center

=	Parallel to the boundary line of the surface indicated by the symbol.	M	Multi-directional.
⊥	Perpendicular to the boundary line of the surface indicated by the symbol.	C	Approximately circular relative to the center of the surface indicated by the symbol.
X	Angular in both directions to the boundary line of the surface indicated by the symbol.	R	Approximately radial relative to the center of the surface indicated by the symbol.

= .005 The numerical value in inches of the width of spacing of roughness is added to the right of the directional indication of the lay symbol as shown.

Fig. 11-1

FINISH MARKS

The "V" finish marks indicate surfaces to be machined or finished. Castings and forgings have finish marks only on those surfaces to be machined. An object machined from stock shall have a general note stating "Finish All Over" (F.A.O.). The finish mark is to be located on the edge of the surface to be machined, and also on extension lines of the surface See Fig. 11-2 for placement of finish mark symbol.

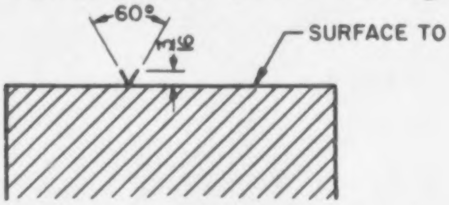


Fig. 11-2

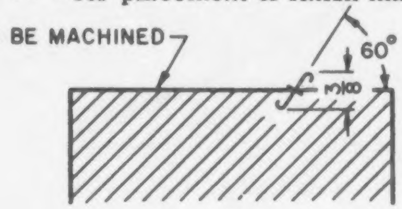


Fig. 11-3

The "*f*" finish mark symbol, as shown in Fig. 11-3 , while still used to some extent, is being superceded by the "V" finish mark.

SURFACE ROUGHNESS

Chart below (Fig. 11-4) shows the typical range of surface roughness values which may be obtained from various production methods.

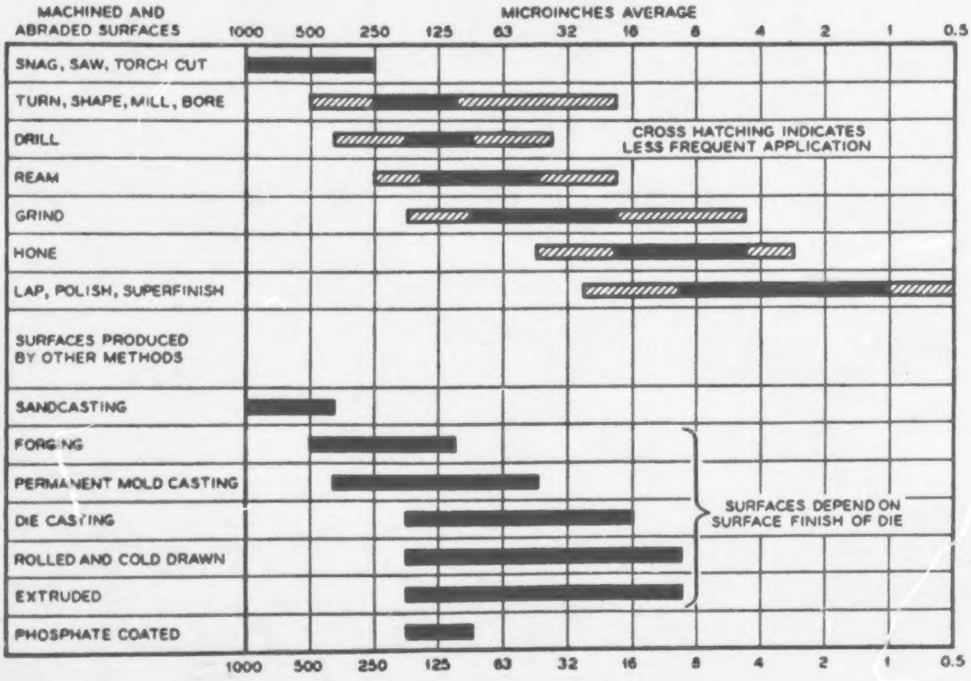


Fig. 11-4

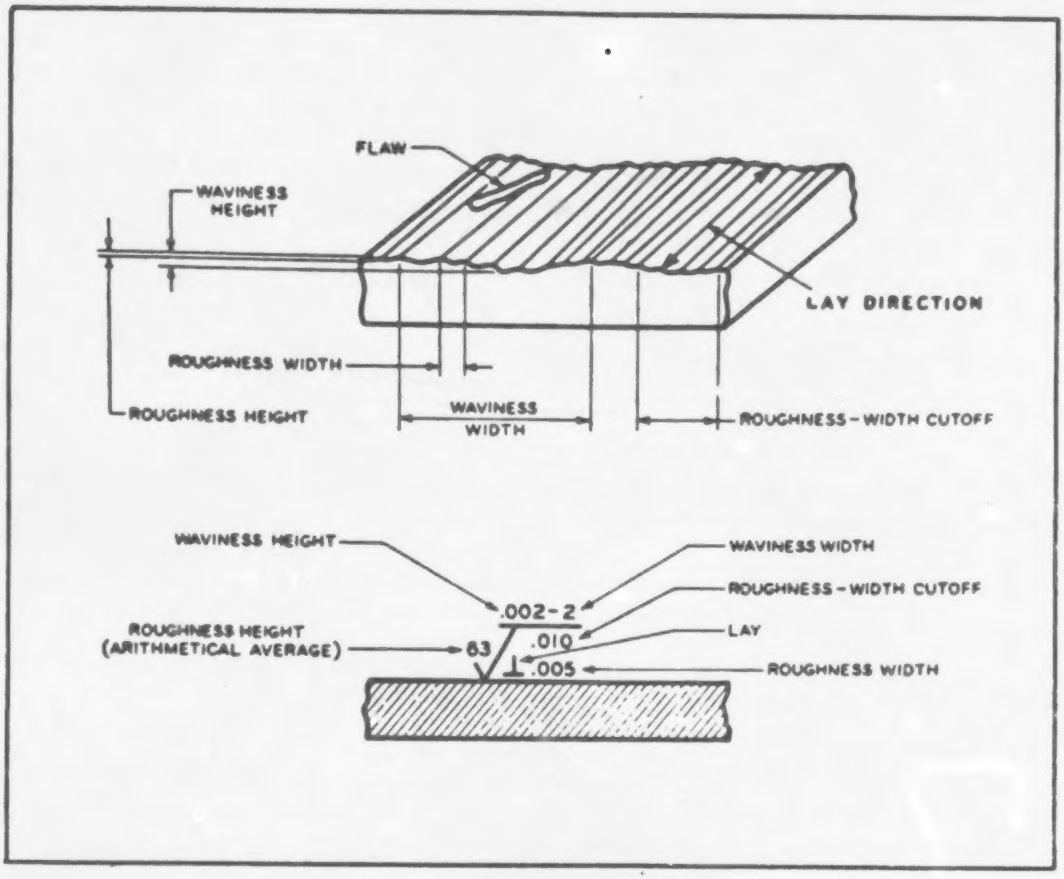

FLAW
WAVINESS HEIGHT
LAY DIRECTION
ROUGHNESS WIDTH
ROUGHNESS HEIGHT
WAVINESS WIDTH
ROUGHNESS-WIDTH CUTOFF
WAVINESS HEIGHT
WAVINESS WIDTH
.002-2
ROUGHNESS-WIDTH CUTOFF
.010
LAY
ROUGHNESS HEIGHT (ARITHMETICAL AVERAGE)
63
⊥
.005
ROUGHNESS WIDTH

Fig. 11-5

DEFINITIONS

Lay: Lay refers to the direction of the tool marks, scratches or grains of a surface.

Waviness: Waviness is the result of work deflection, strain within the part, vibration, warping, or other causes.

Roughness: Roughness refers to the small peaks and valleys found on any surface, no matter how smooth in appearance.

Microinch: One millionth of an inch (0.000001").

ASSIGNMENT

1. List the average surface quality ranges in microinches for the following processes:

   drilling
   reaming
   grinding
   turning
   shaping
   honing
   milling
   lapping
   boring

2. List the average surface quality finishes in microinches produced by these other methods:

   sandcasting
   forging
   permanent mold casting

3. Define microinch and its value.
4. Define the six lay symbols
5. Sketch the √ symbol and locate the five surface quality values in their respective locations.
6. Define:

   lay
   flaw
   waviness height
   waviness width
   roughness width
   roughness height

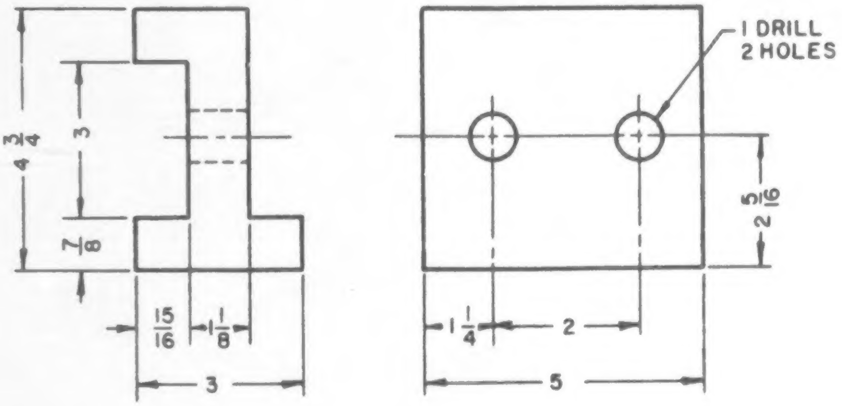
7. When are ∨ finishes used on a casting or forging?
8. When would 'Finish All Over' be used on a drawing?
9. Sketch a ∨ mark and give the height and included angle.
10. Where should the ∨ or √ marking be placed?

SECTION IV *ORTHOGRAPHIC PROJECTIONS*

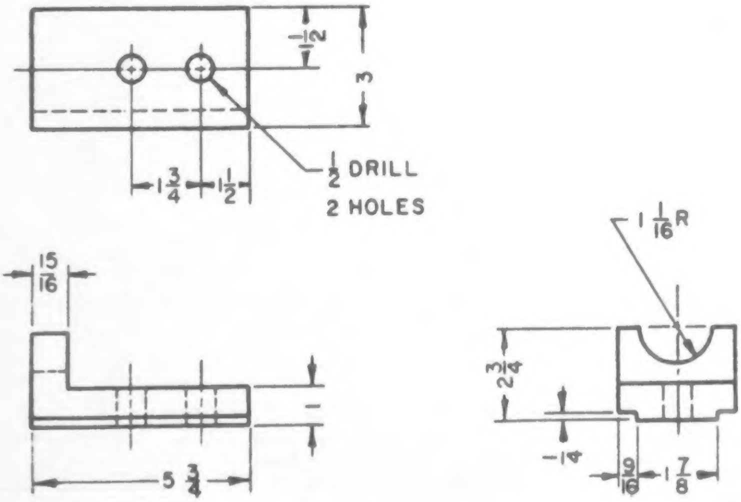
Unit 12 ORTHOGRAPHIC DRAWING - STRAIGHT SURFACES

ASSIGNMENT

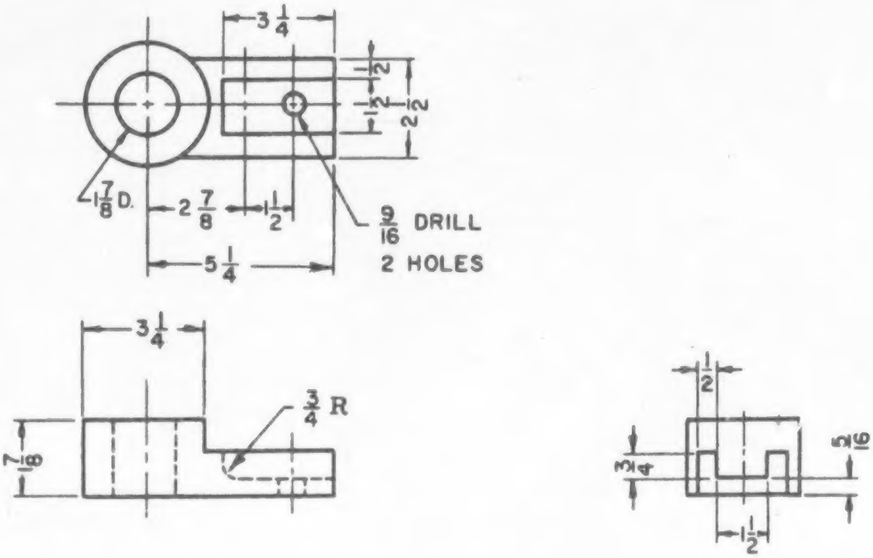
Problems 12-1 through 12-6 are incomplete. Redraw the views to full scale and add the missing lines to complete the drawings. Review Unit 7, Orthographic Concept, page 52


4 3/4
3
7/8
15/16
1 1/8
3
1 DRILL
2 HOLES
2 5/16
1 1/4
2
5

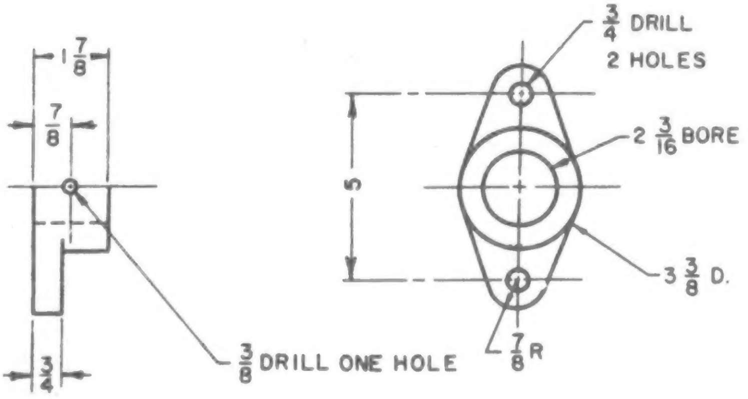
PROBLEM 12-1


1/2
3
1 3/4
1 1/2
1/2 DRILL
2 HOLES
15/16
1
5 3/4
1 1/16 R
2 3/4
1/4
9/16
1 7/8

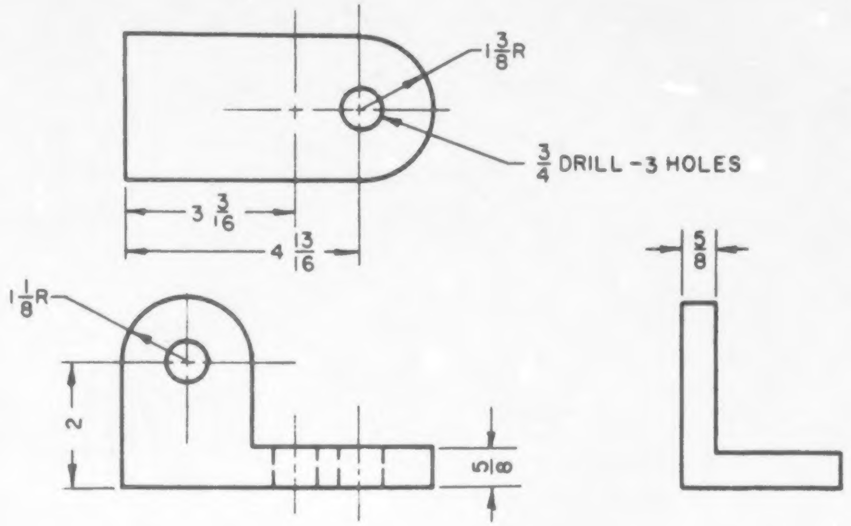
PROBLEM 12-2


3 1/4
1/2
1 1/2
2 1/2
1 7/8 D.
2 7/8
1 1/2
9/16 DRILL
2 HOLES
5 1/4
3 1/4
3/4 R
7/8
1/2
3/4
5/16
1 1/2

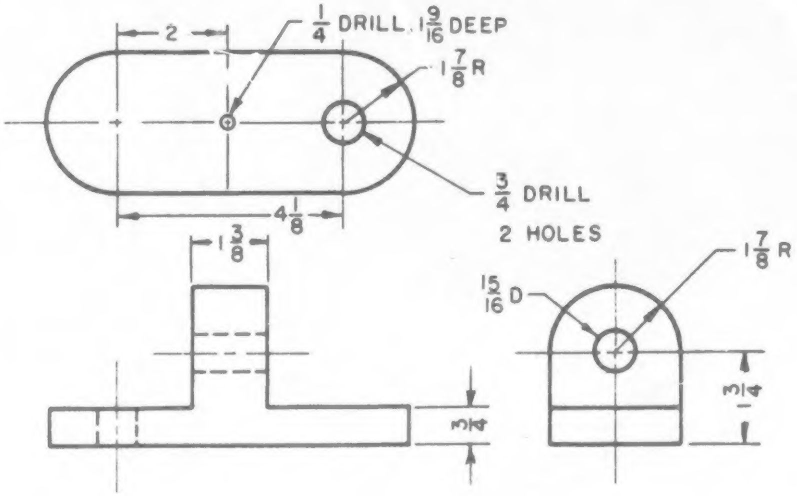
PROBLEM 12-3


1 7/8
7/8
3/4
3/8 DRILL ONE HOLE
3/4 DRILL
2 HOLES
2 3/16 BORE
5
3 3/8 D.
7/8 R

PROBLEM 12-4

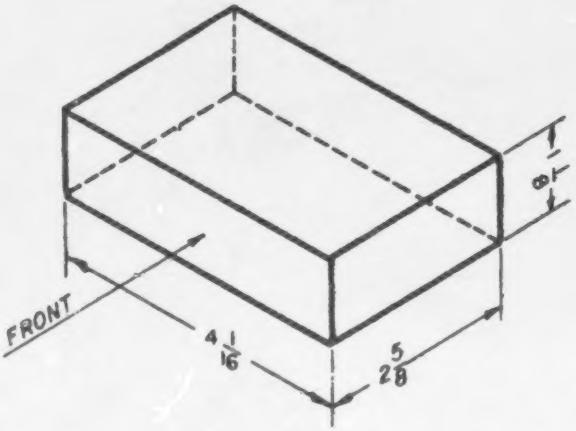

1 3/8 R
3/4 DRILL -3 HOLES
3 3/16
4 13/16
5/8
1 1/8 R
2
5/8

PROBLEM 12-5


2
1/4 DRILL, 1 9/16 DEEP
1 7/8 R
3/4 DRILL
2 HOLES
4 1/8
1 3/8
15/16 D
1 7/8 R
3/4
1 3/4

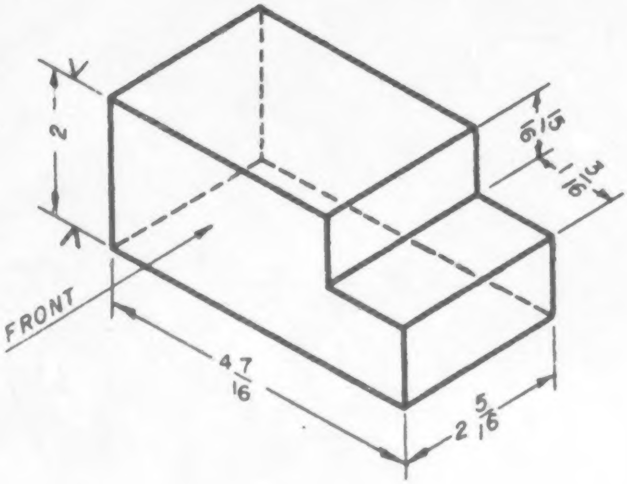
PROBLEM 12-6

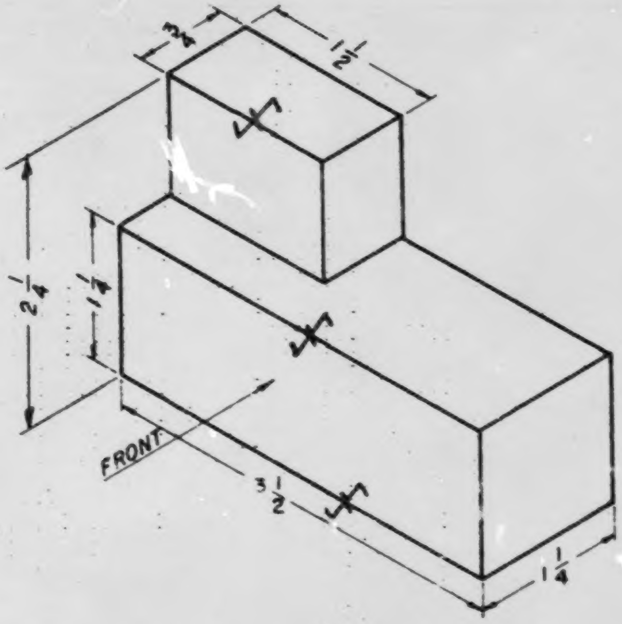
PROBLEM 12-7 Draw the front, top and right-side views to full scale.


FRONT
4 1/16
2 5/8
1 1/8

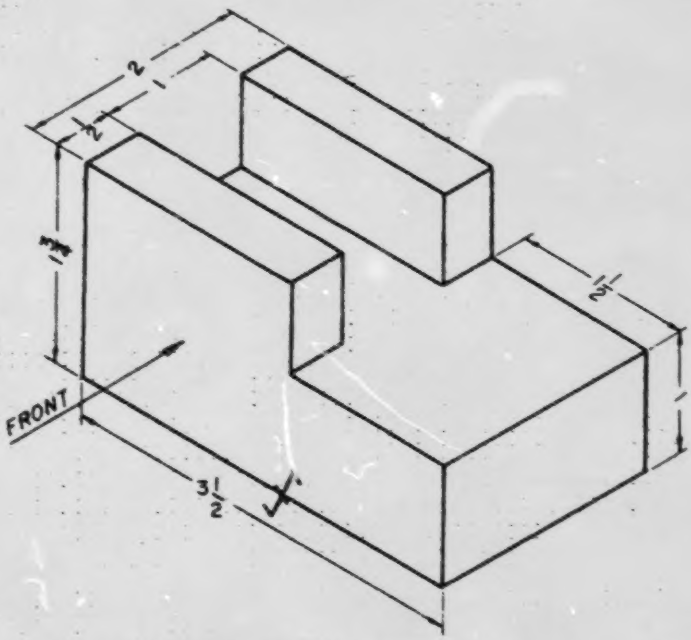
NOTE: 63/125 FAO

PROBLEM 12-8 Draw the front, top and right-side views to full scale.

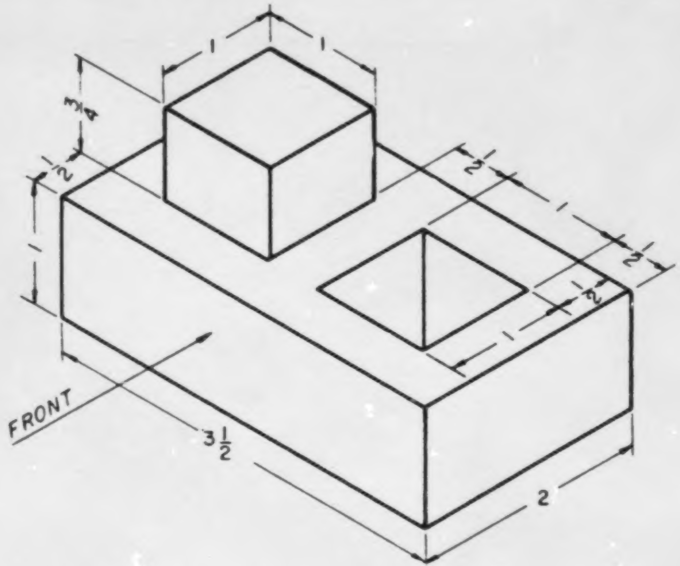

2
15/16
1 3/16
FRONT
4 7/16
2 5/16


3/4
1 1/2
2 1/4
1 1/4
FRONT
3 1/2
1 1/4

PROBLEM 12-9 Draw the front, top and right-side views to full scale.

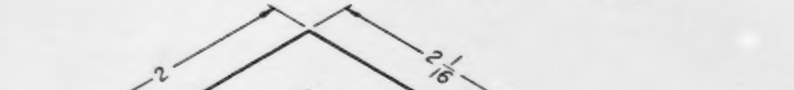

2
1
1/2
1 3/4
1 1/2
1
FRONT
3 1/2

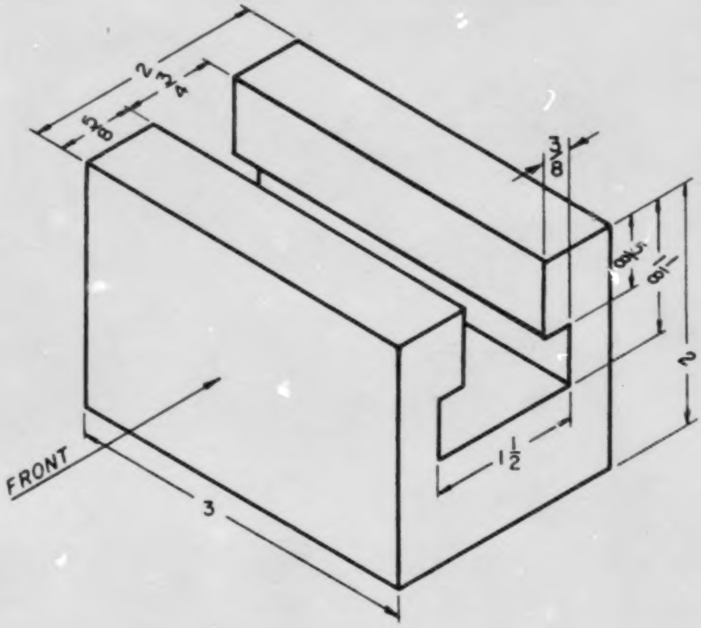
PROBLEM 12-10 Draw the front, top and right-side views to full scale.


1
1
3/4
1/2
1
1/2
1
1/2
1/2
1
FRONT
3 1/2
2

PROBLEM 12-11 Draw the front, top and right-side views to full scale.

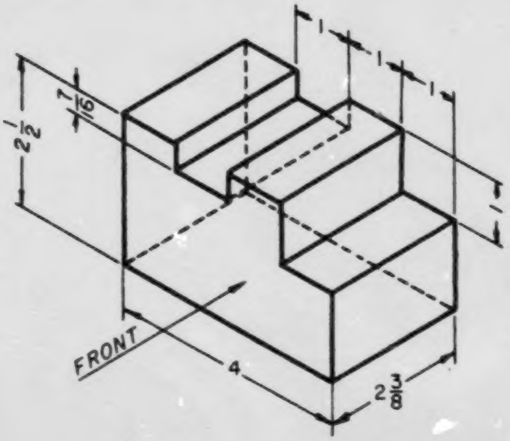
PROBLEM 12-12 Draw the front, top and right-side views to full scale.

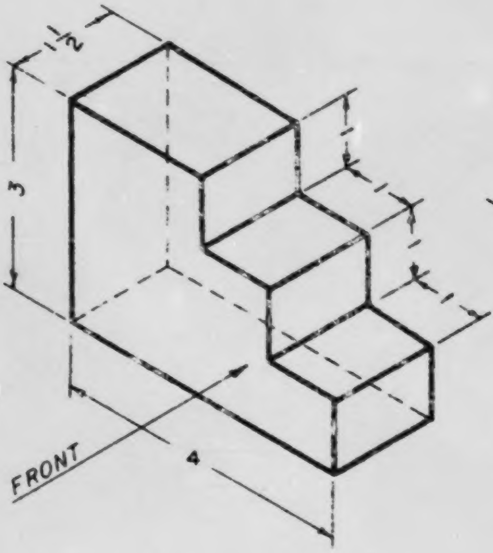

2
2 1/16
3/4
2 1/8
1/2
2 1/2
1/2
1/2
1 3/4
FRONT
4 1/8


2 3/4
5/8
3/8
5/8
1 1/8
2
1 1/2
3
FRONT

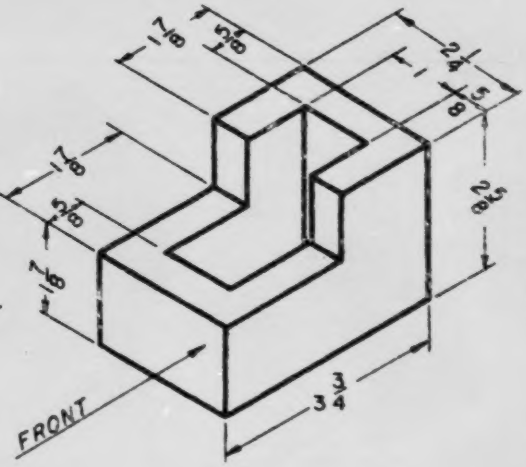
PROBLEM 12-13 Draw the front, top and right-side views to full scale.

PROBLEM 12-14 Draw the front, top and right-side views to full scale.

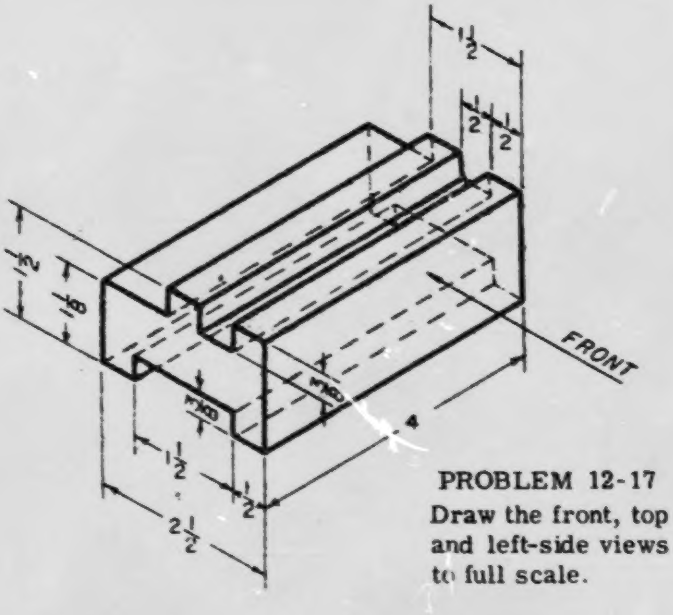

1
1
1
7/16
2 1/2
1
FRONT
4
2 3/8


1 1/2
3
1
1
1
4
FRONT

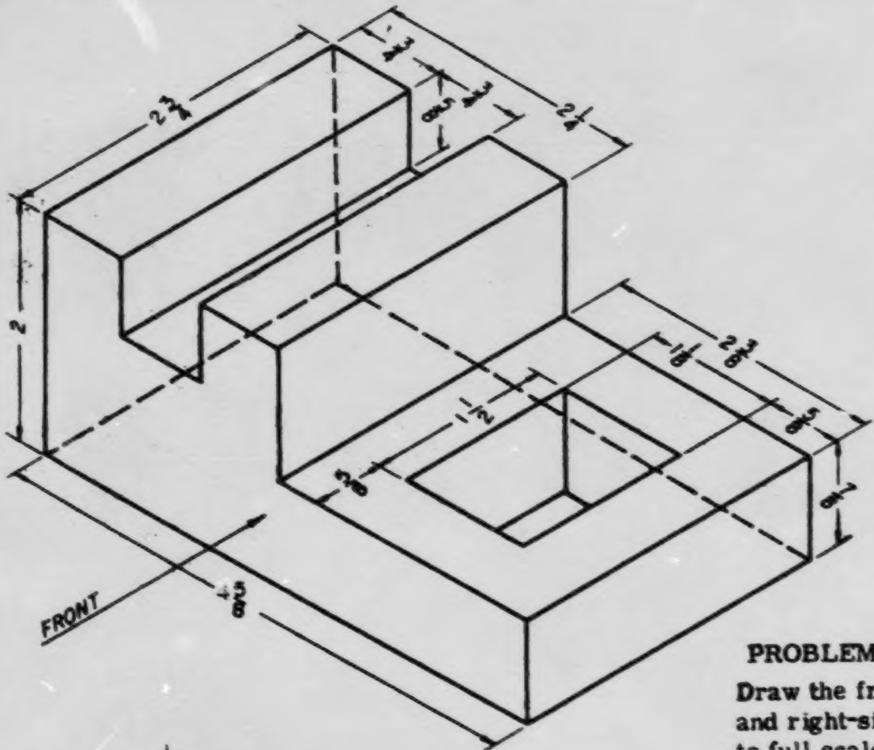
PROBLEM 12-15
Draw the front, top and right-side views to full scale.


1 7/8
5/8
2 1/4
1
5/8
2 5/8
1 7/8
5/8
7/8
3 3/4
FRONT

PROBLEM 12-16
Draw the front, top and right-side views to full scale.

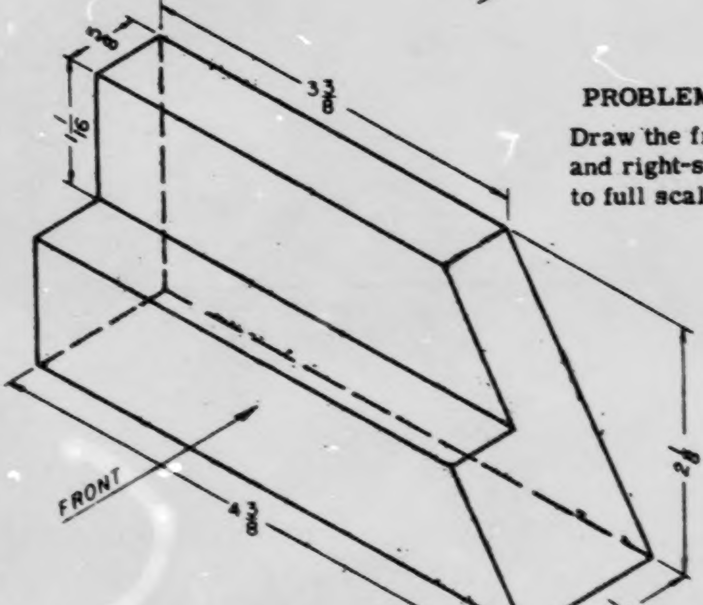

1 1/2
1/2
1/2
1 1/2
1 1/8
3/8
3/8
1 1/2
1/2
2 1/2
4
FRONT

PROBLEM 12-17
Draw the front, top and left-side views to full scale.


2 3/4
3/4
3/4
5/8
2 1/4
2
2 3/8
1/8
1 1/2
5/8
5/8
7/8
4 5/8
FRONT

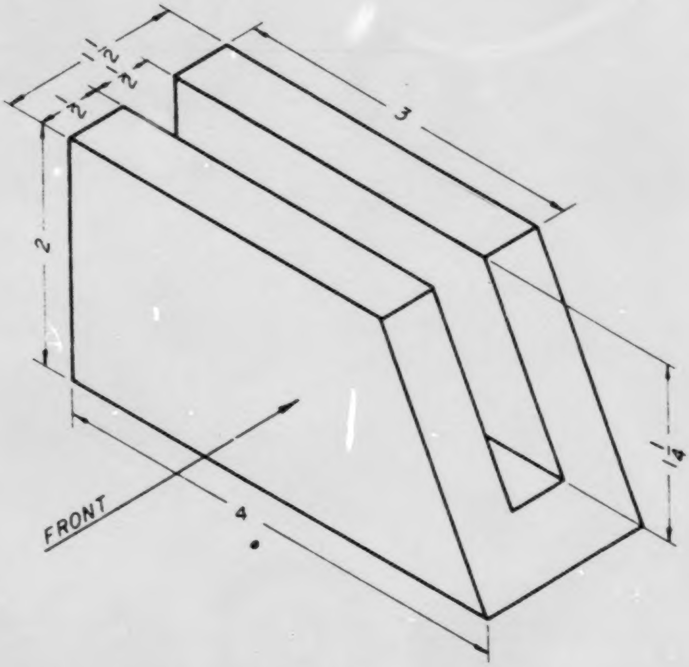
PROBLEM 12-18

Draw the front, top, and right-side views to full scale.

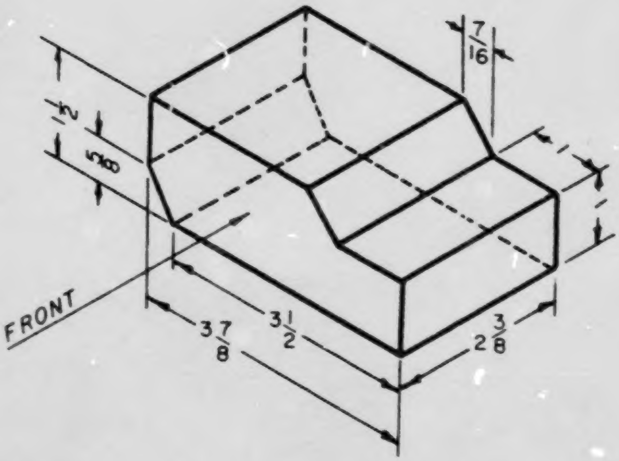

3/8
1 1/16
3 3/8
2 1/8
4 3/8
1 1/2
FRONT

PROBLEM 12-19

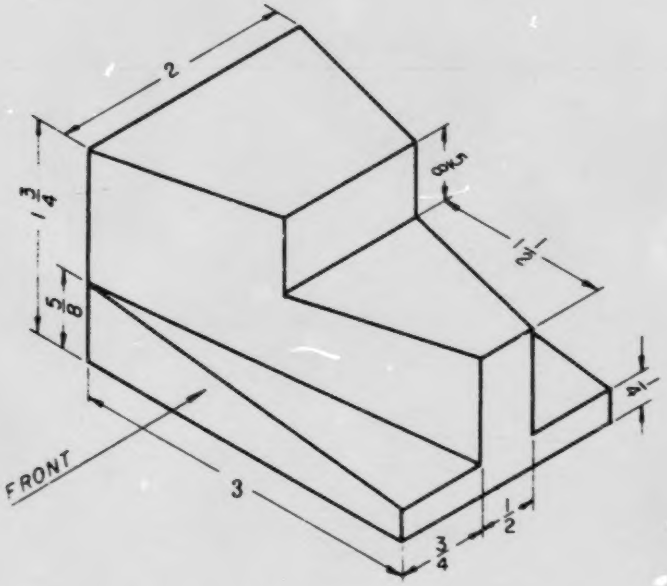
Draw the front, top, and right-side views to full scale.


1 1/2
1/2
1/2
1/2
3
2
1 1/4
4
FRONT

PROBLEM 12-20 Draw the front, top and right-side views to full scale.

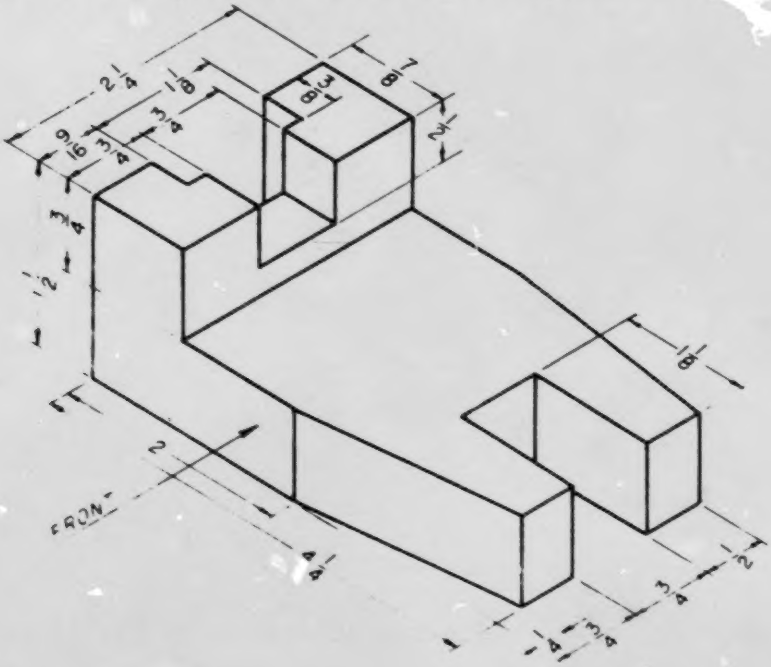

7/16
1 1/2
5/8
1
1
3 7/8
3 1/2
2 3/8
FRONT

PROBLEM 12-21 Draw the front, top and right-side views to full scale.

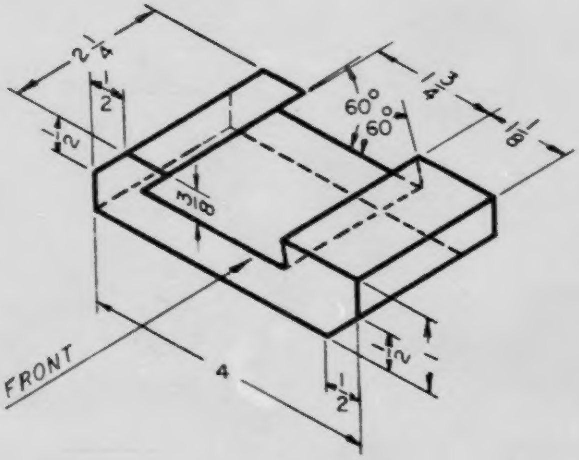

2
1 3/4
5/8
5/8
1 1/2
1/4
FRONT
3
1/2
3/4

PROBLEM 12-22 Draw the front, top and right-side views to full scale.

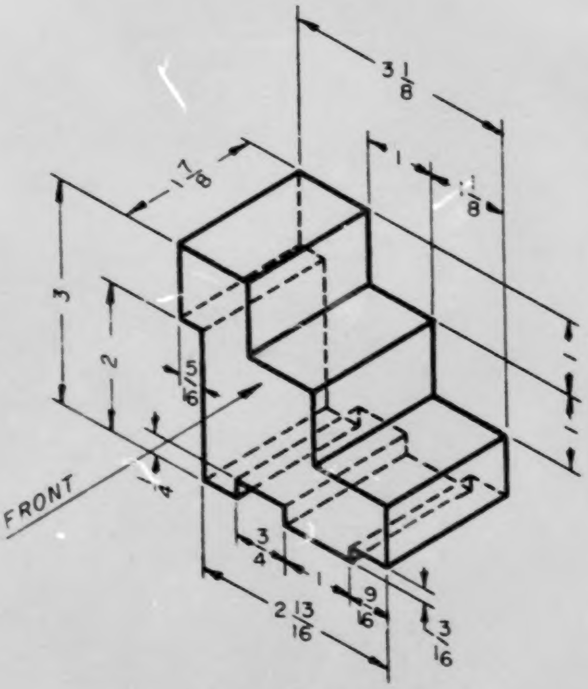
PROBLEM 12-23 Draw the front, top and right-side views to full scale.

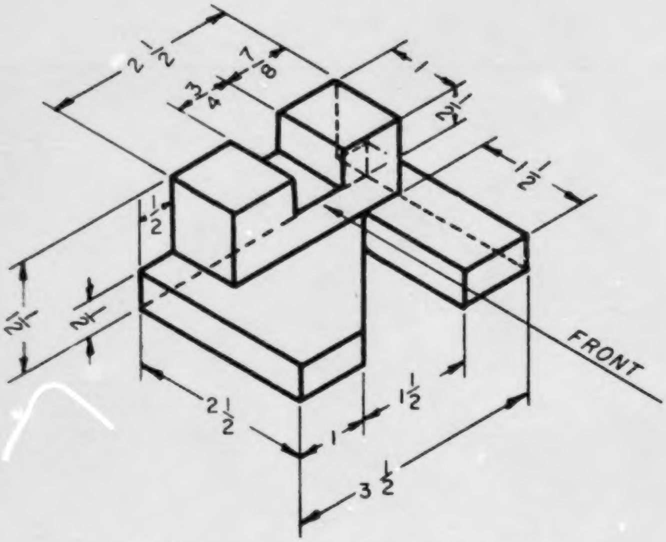

2 1/4
1 1/8
3/8
7/8
9/16
3/4
3/4
1/4
3/4
1 1/2
1 1/8
2
FRONT
4 1/4
1/2
3/4
1/4
3/4
1

PROBLEM 12-24 Draw the front, top and right-side views to full scale.

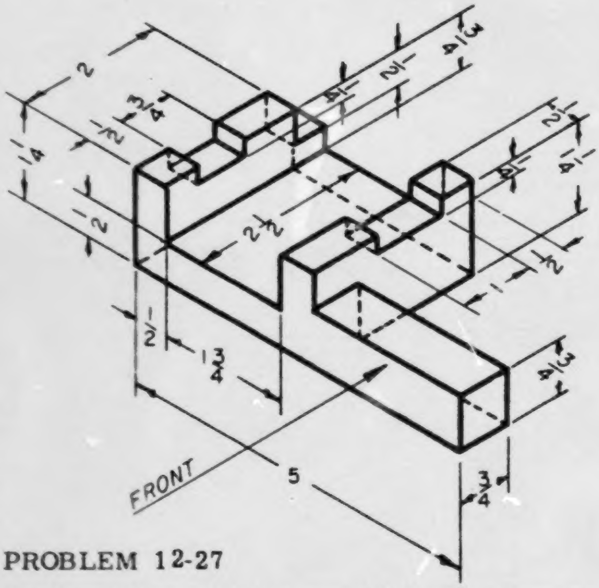

2 1/4
1/2
1/2
3/8
60°
60°
3/4
1/8
FRONT
4
1/2
1/2

PROBLEM 12-25 Draw the front, top and right-side views to full scale.


3 1/8
1 7/8
1
1/8
3
2
5/16
1/4
1
1
1
FRONT
3/4
1
9/16
2 13/16
3/16

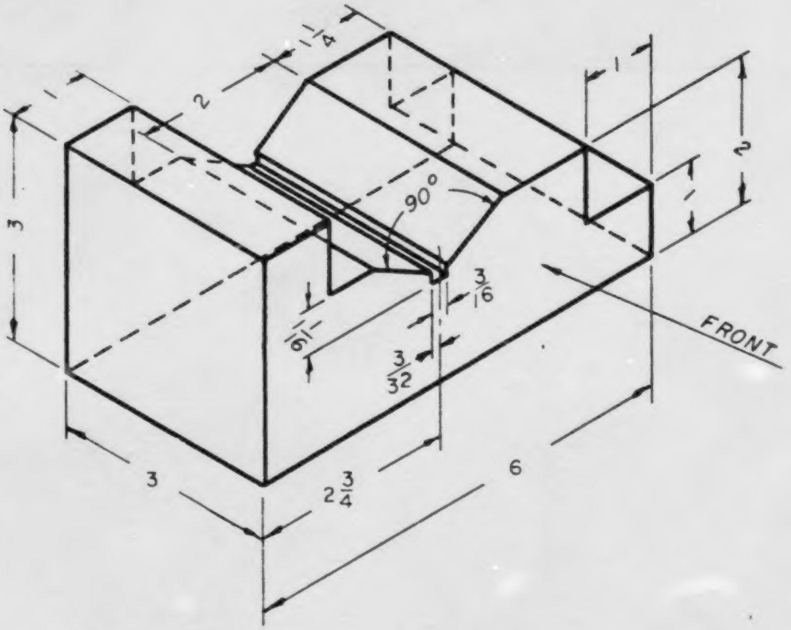

2 1/2
3/4
7/8
1
1/2
1 1/2
1/2
1/2
1/2
FRONT
2 1/2
1
1 1/2
3 1/2

PROBLEM 12-26 Draw the front, top and left-side views to full scale.

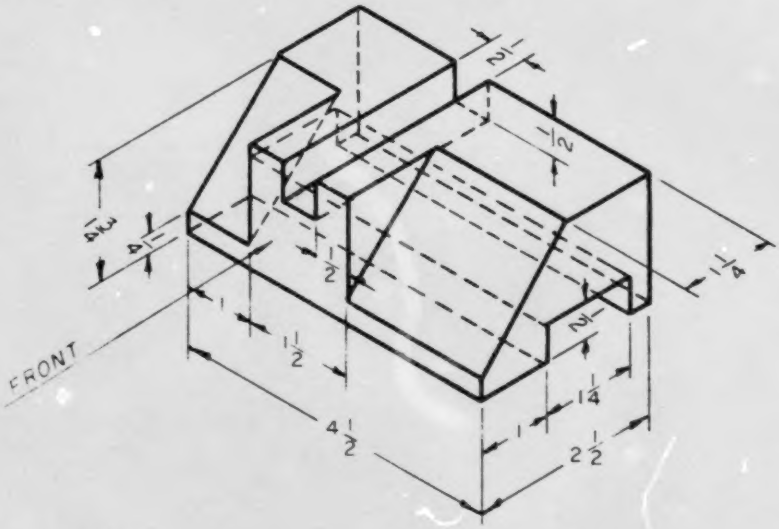

2
3/4
1/2
1/4
1/2
1/8
1/2
3/4
2 1/2
1/2
1/8
1/4
1/2
1
1/2
1 3/4
3/4
FRONT
5
3/4

PROBLEM 12-27

The front, top, left-side, and right-side views are required. The left-side and right-side views are to terminate with the middle of the 1 3/4 by 2 1/2 area. This is a common practice intended to clarify each view rather than to overburden each view with confusing object and hidden lines.

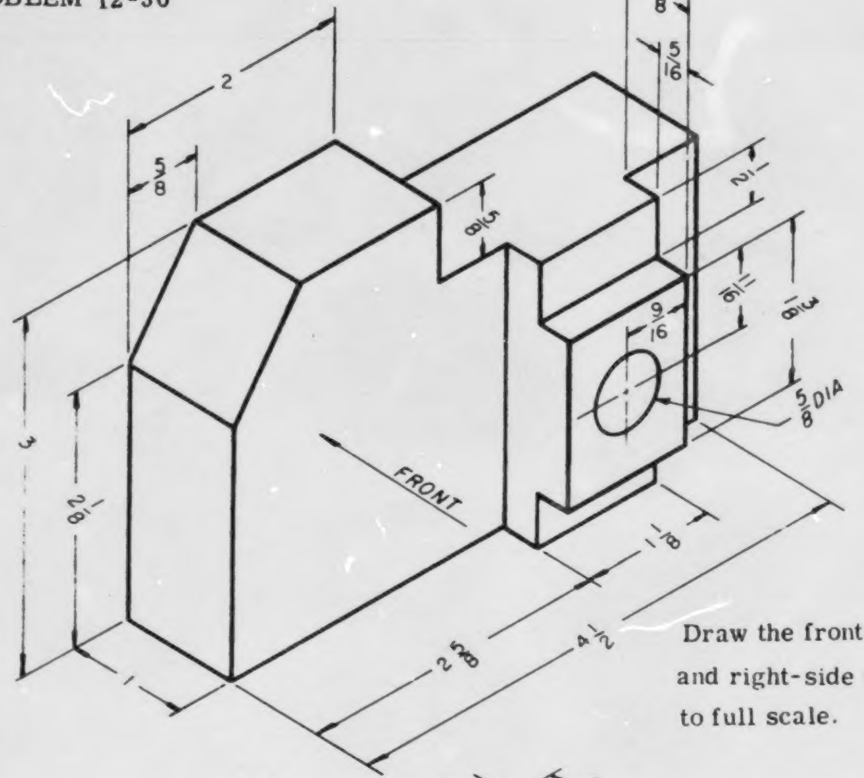

1
2
1 1/4
1
2
1
3
90°
3/16
1/16
3/32
FRONT
3
2 3/4
6

PROBLEM 12-28 Draw the front, top and right-side views to full scale.


1/2
1/2
3/4
1/4
1/2
1 1/4
1/2
1
1 1/2
FRONT
4 1/2
1
1 1/4
2 1/2

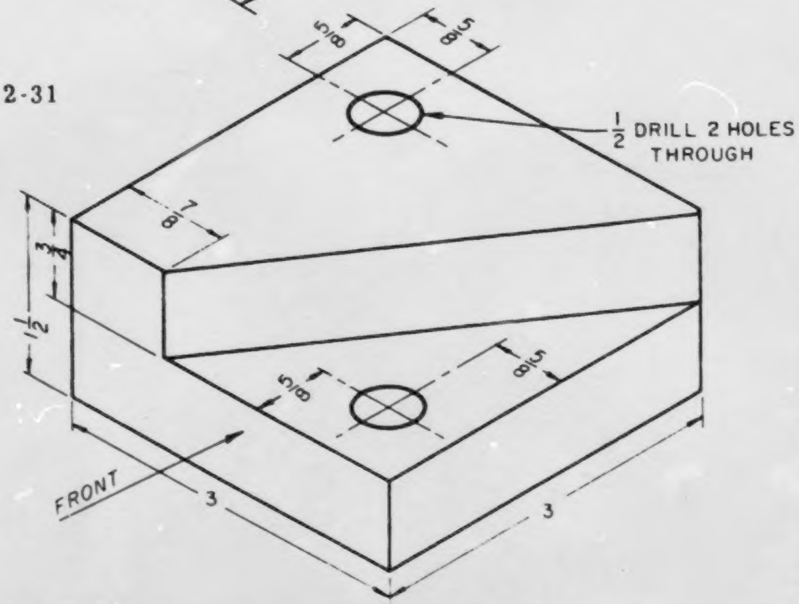
PROBLEM 12-29 Draw the front, top and right-side views to full scale.

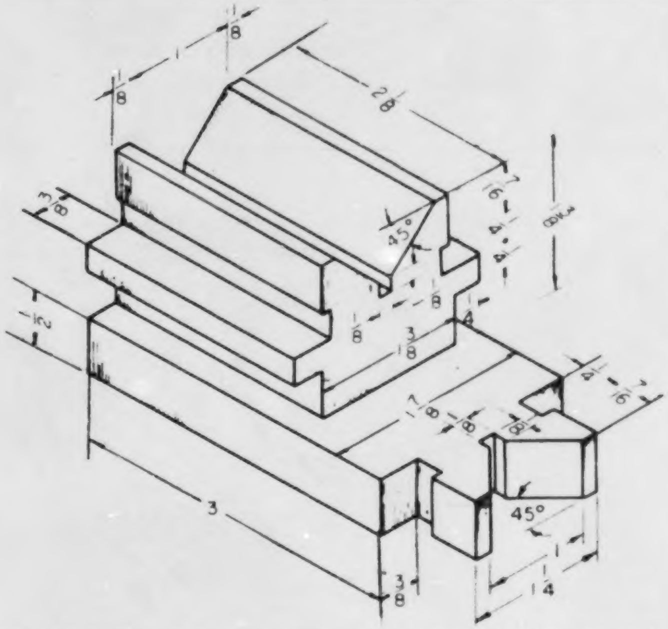
PROBLEM 12-30


2
5/8
5/8
5/16
5/8
1/2
11/16
1 3/8
9/16
5/8 DIA
FRONT
3
2 1/8
1
1 1/8
2 5/8
4 1/2

Draw the front, top and right-side views to full scale.

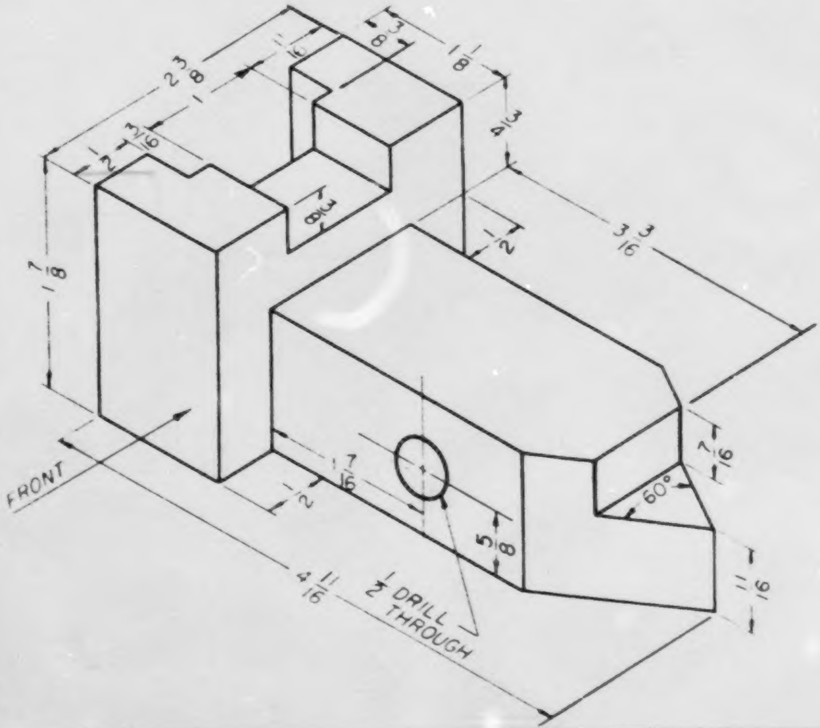
PROBLEM 12-31


5/8
5/8
1/2 DRILL 2 HOLES THROUGH
7/8
3/4
1 1/2
5/8
5/8
FRONT
3
3


1/8
1/8
2 1/8
3/8
45°
3/16
1/4
1/4
3/8
1/2
1/8
1 3/8
1/8
7/8
1/8
1/8
1/4
3/16
45°
3
3/8
1
1 1/4

PROBLEM 12-32 Draw the front, top and right-side views to full scale.

PROBLEM 12-33 Draw the front, top and right-side views to full scale.


2 3/8
11/16
3/8
1 1/8
1/2
3/16
1
1/4
3/8
1 7/8
1/2
3 3/16
FRONT
1 7/16
1/2
5/8
7/16
60°
11/16
4 11/16
1/2 DRILL THROUGH

Unit 13 ORTHOGRAPHIC DRAWING - CURVED SURFACES

The shape of an orthographic view of a cylindrical part depends upon the direction from which it is viewed. (See right end view, Fig. 13-2.) If we look at this same piece from a distant point in a line perpendicular to the longitudinal axis, the stock appears to be a rectangle. (See front view below.) The circular end surface appears as a straight line when the stock is viewed from this second position.

With circles, two center lines at right angles to each other are used to indicate the center or axis. (See right end view, Fig. 13-2.) We learned previously that a center line is used to indicate a central location but may not be entirely true of circles, as a circle or hole may not be centrally located on or in a piece. (See Fig. 13-1.) Nevertheless, two center lines at right angles to each other and intersecting at the center of the circle are always used when a hole or circular part is shown on a sketch.

When sketching simple cylindrical parts it is necessary to draw only two views, a circular end view and a front view. The circular end view should be drawn at the right of the front view. It is good practice to draw the circular view first and then project the lines to the left to make up the front view.

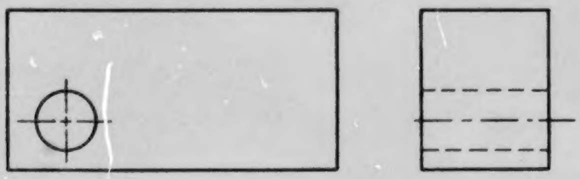


Fig. 13-1

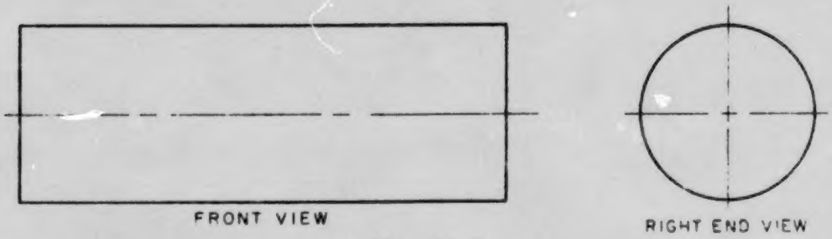


Fig. 13-2

Dimensioning Circles and Arcs

Circles and arcs of circles are dimensioned by the use of radius or diameter lines as shown below:

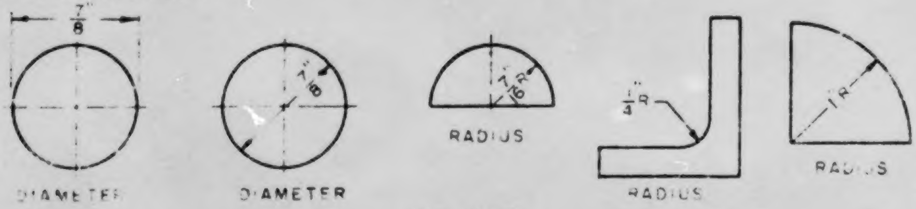
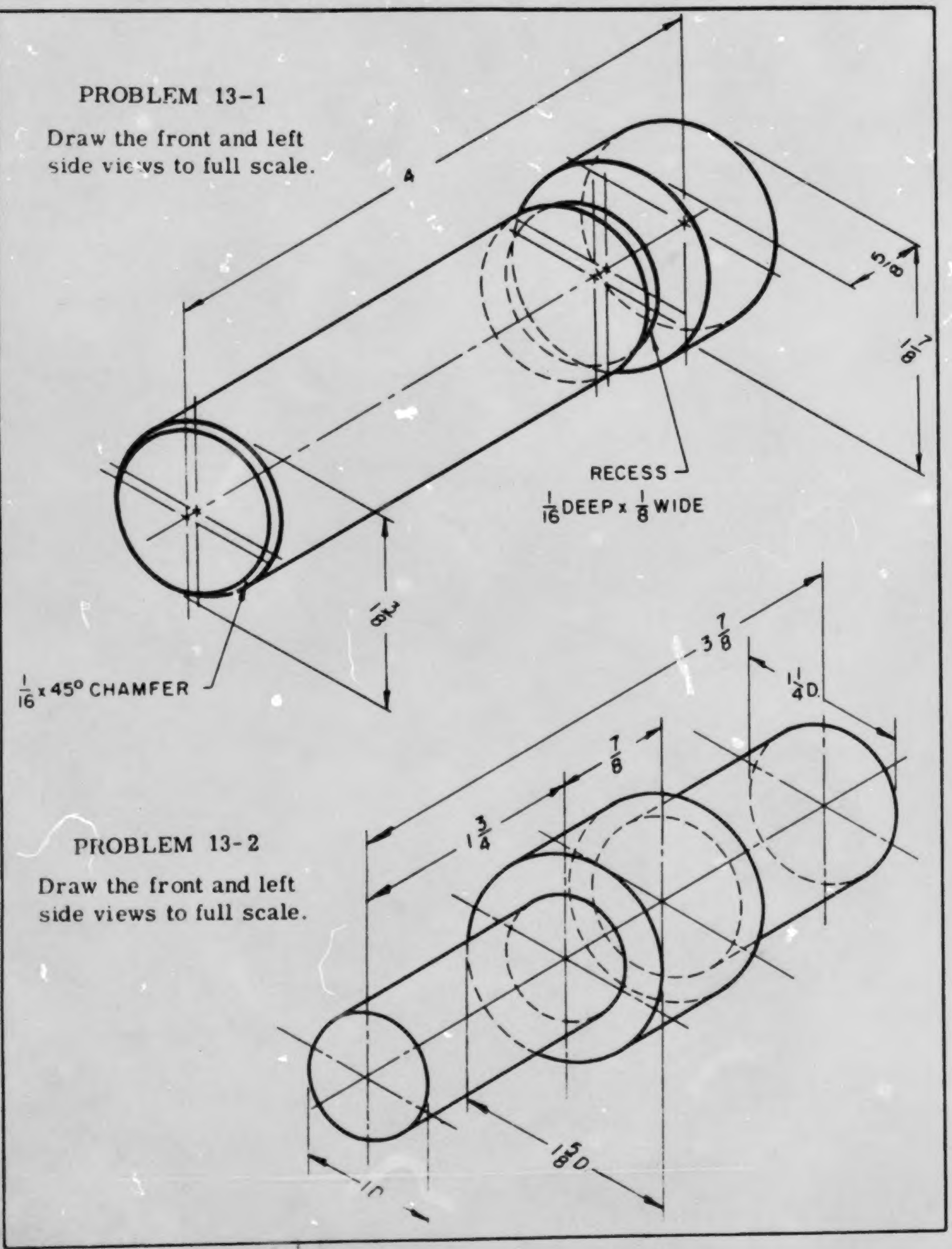


Fig. 13-3

ASSIGNMENT

Prepare drawings (Problems 13-1 through 13-17), following instructions given.



PROBLEM 13-1

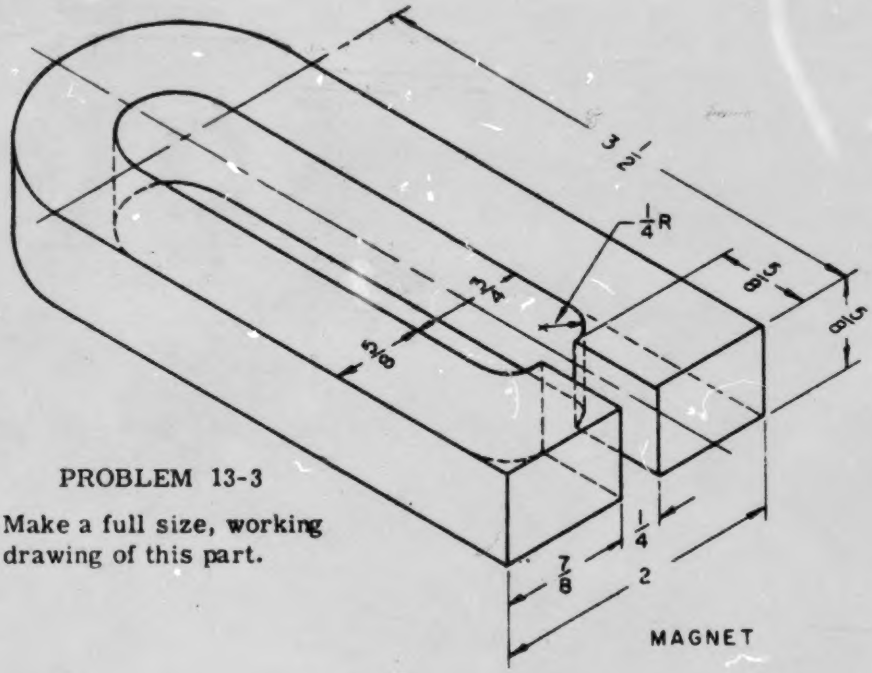
Draw the front and left side views to full scale.

4
5/8
1 7/8
RECESS
1/16 DEEP x 1/8 WIDE
1 3/8
1/16 x 45° CHAMFER

PROBLEM 13-2

Draw the front and left side views to full scale.

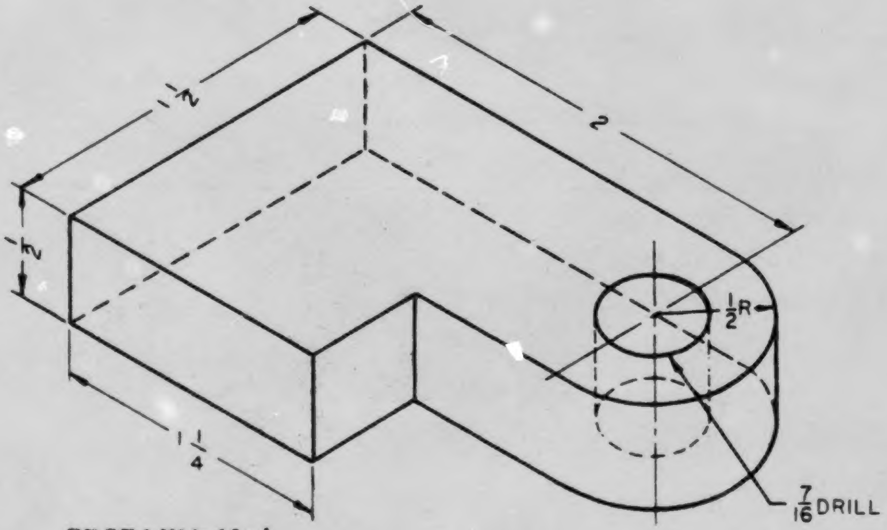
3 7/8
1 1/4 D.
7/8
1 3/4
1 5/8 D
1 D


3 1/2
1/4 R
5/8
5/8
3/4
5/8
1/4
7/8
2

PROBLEM 13-3

Make a full size, working drawing of this part.

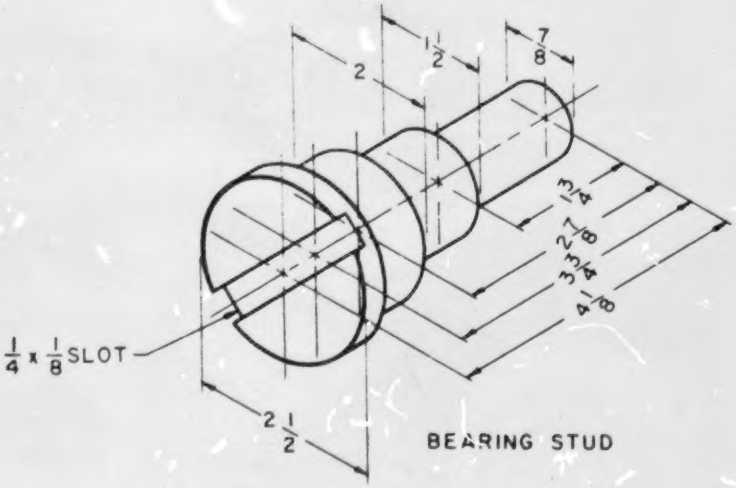
MAGNET


1 1/2
2
1/2
1/2 R
1 1/4
7/16 DRILL

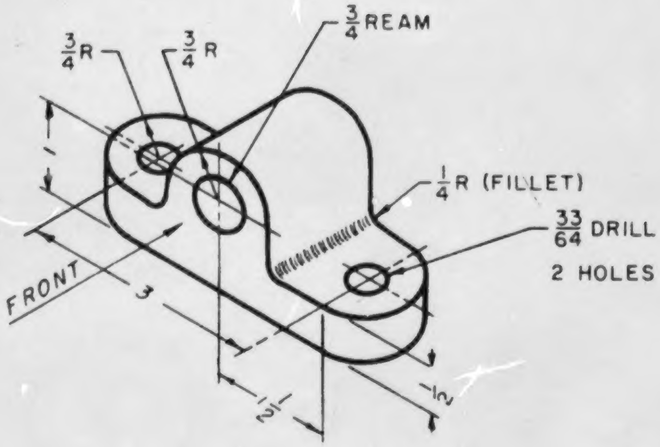
PROBLEM 13-4

Make a full size, three-view working drawing.

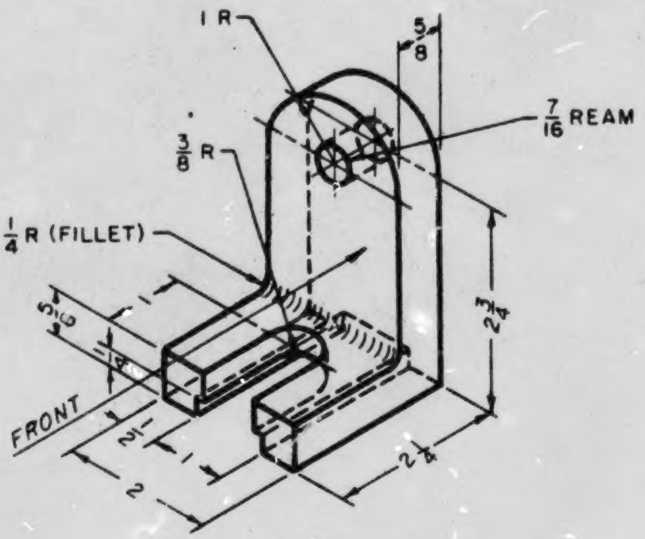
COUNTER WEIGHT


2
1 1/2
7/8
1 3/4
2 7/8
3 3/4
4 1/8
1/4 x 1/8 SLOT
2 1/2
BEARING STUD

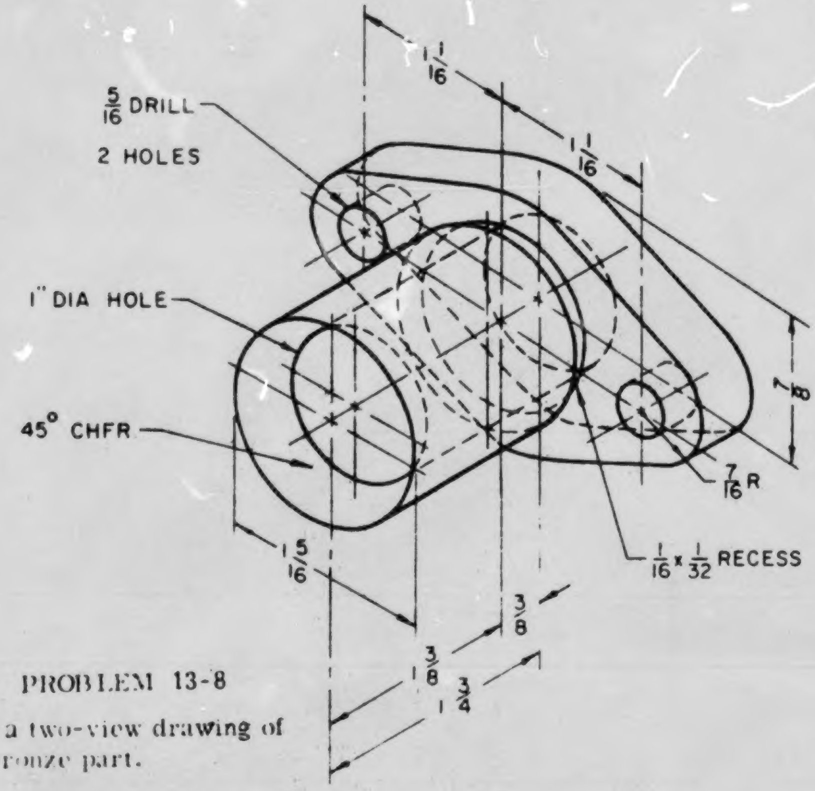
PROBLEM 13-5 Make a full size, two-view drawing.


3/4 R
3/4 R
3/4 REAM
1
1/4 R (FILLET)
33/64 DRILL
2 HOLES
FRONT
3
1 1/2
1/2

PROBLEM 13-6 Draw the front, top and right-side views to full scale.

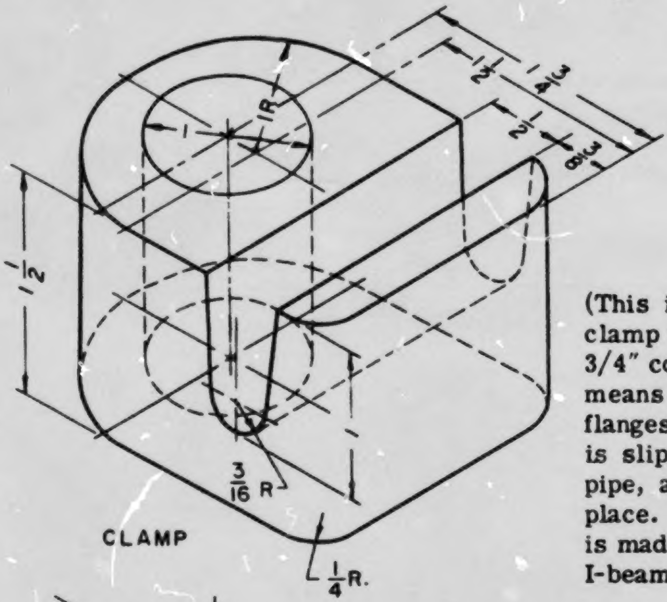

1 R
5/8
7/16 REAM
3/8 R
1/4 R (FILLET)
5/16
1
1/4
FRONT
1/2
1
2
2 1/4
2 3/4

PROBLEM 13-7 **Draw the front, top and right-side views to full scale.**


1 1/16
5/16 DRILL
2 HOLES
1 1/16
1" DIA HOLE
45° CHFR
7/8
7/16 R
1/16 x 1/32 RECESS
1 5/16
3/8
1 3/8
1 3/4

PROBLEM 13-8

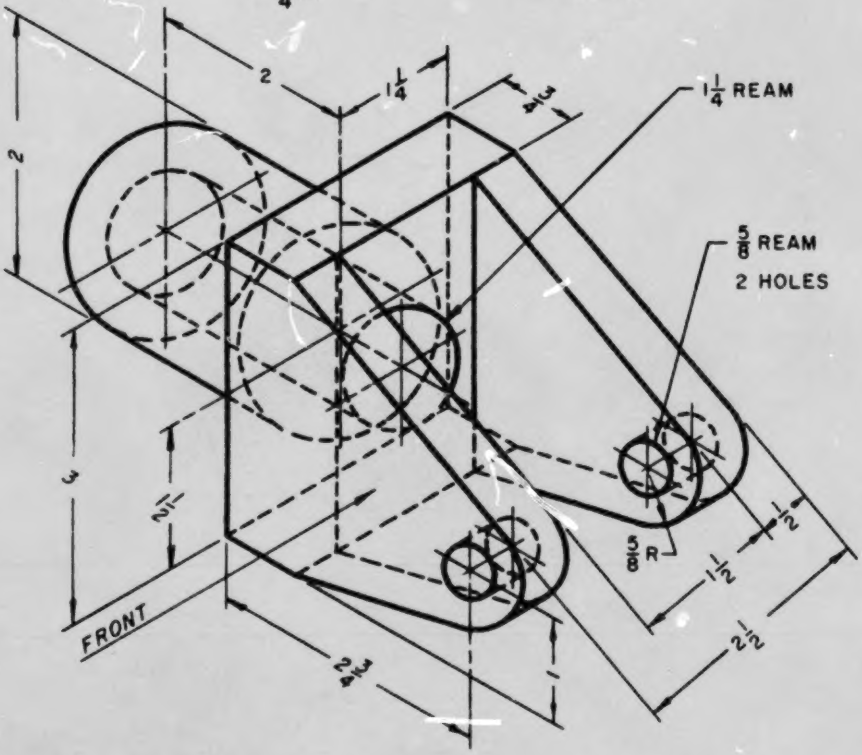
Make a two-view drawing of this bronze part.


1/2
1 3/4
1/2
3/8
1R
1
1 1/2
3/16 R
CLAMP
1/4 R.

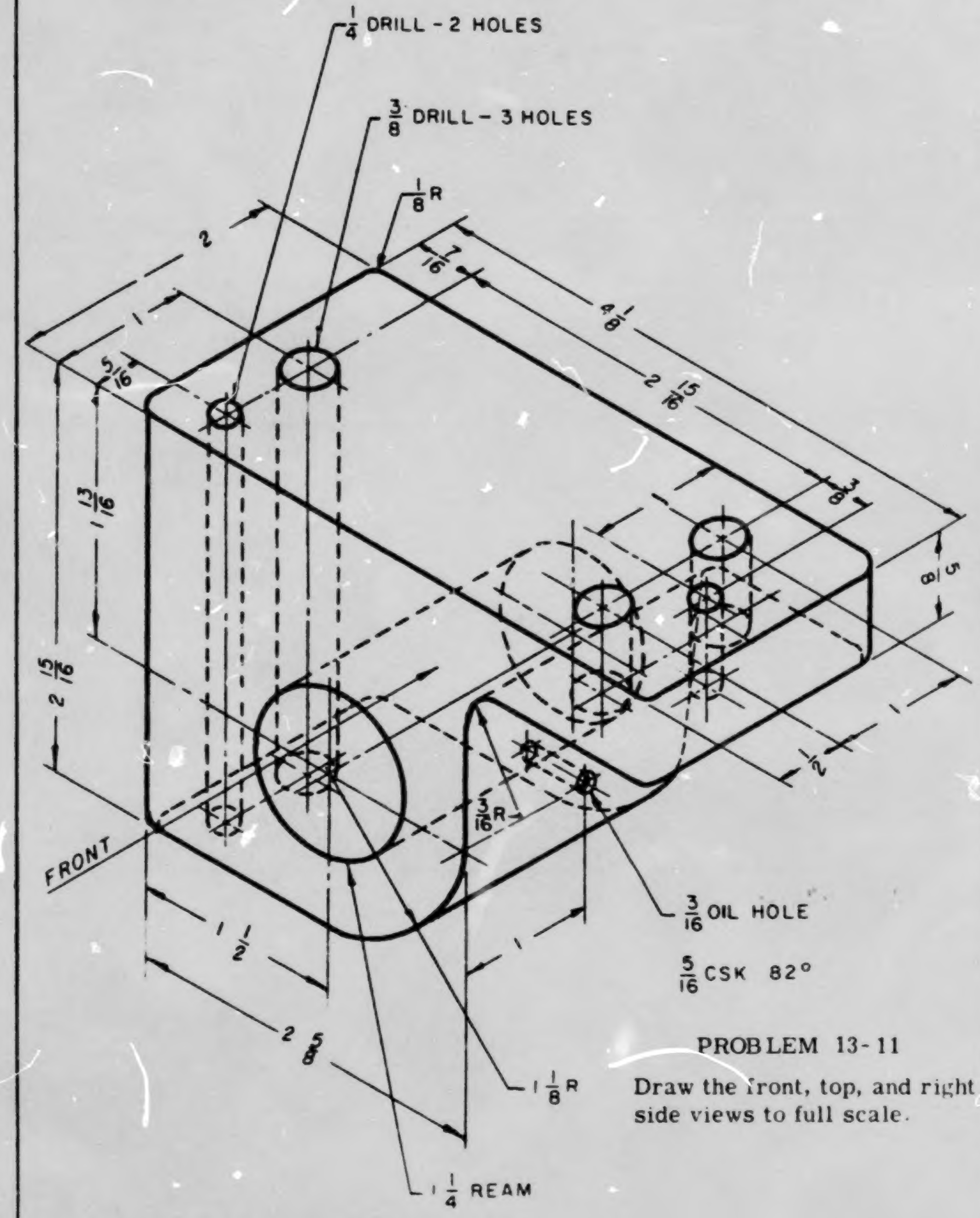
PROBLEM 13-9

Make a three-view orthographic sketch to full scale.

(This isometric sketch is of a clamp used to support a standard 3/4" conduit. It was made as a means of attaching conduit to the flanges of I-beams. The clamp is slipped over the end of the pipe, a set screw holding it in place. The 1/2" tapered slot is made to fit the flanges of the I-beam.)


2
1 1/4
3/4
1 1/4 REAM
2
5/8 REAM
2 HOLES
3
2 1/2
FRONT
5/8 R
1 1/2
1/2
2 3/4
1
2 1/2

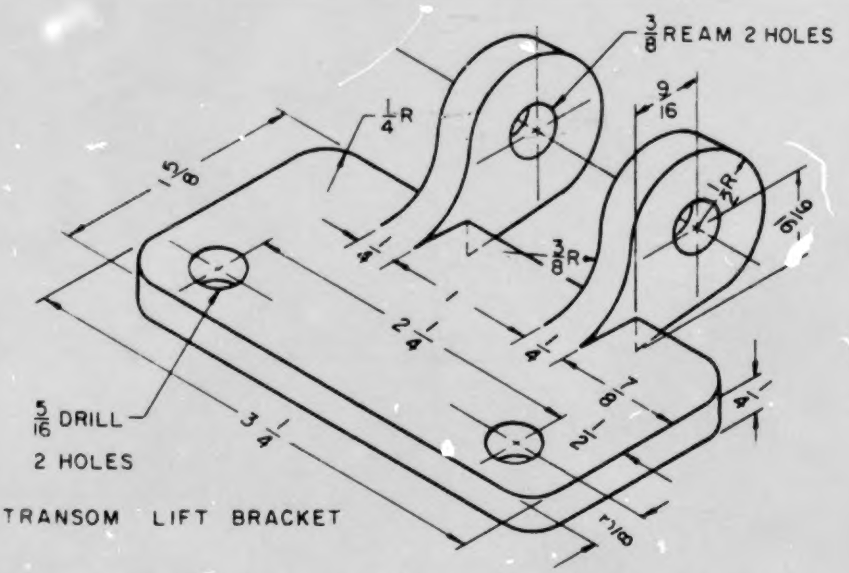
PROBLEM 13-10 Draw the front, top and right-side views to full scale.



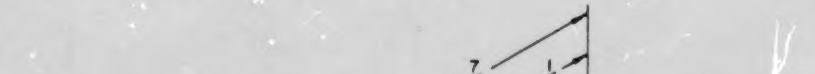
$\frac{1}{4}$ DRILL - 2 HOLES
$\frac{3}{8}$ DRILL - 3 HOLES
$\frac{1}{8}$ R
2
$\frac{7}{16}$
$4\frac{1}{8}$
1
$\frac{5}{16}$
$2\frac{15}{16}$
$\frac{3}{8}$
$\frac{5}{8}$
$1\frac{13}{16}$
$2\frac{15}{16}$
1
$\frac{1}{2}$
$\frac{3}{16}$ R
FRONT
$1\frac{1}{2}$
1
$2\frac{5}{8}$
$\frac{3}{16}$ OIL HOLE
$\frac{5}{16}$ CSK 82°
$1\frac{1}{8}$ R
$1\frac{1}{4}$ REAM

PROBLEM 13-11

Draw the front, top, and right side views to full scale.


3/8 REAM 2 HOLES
9/16
1/4 R
1 5/8
1/2 R
9/16
3/8 R
1/4
1
2 1/4
1/4
7/8
1/2
1/4
5/16 DRILL
2 HOLES
3 1/4
5/8
TRANSOM LIFT BRACKET

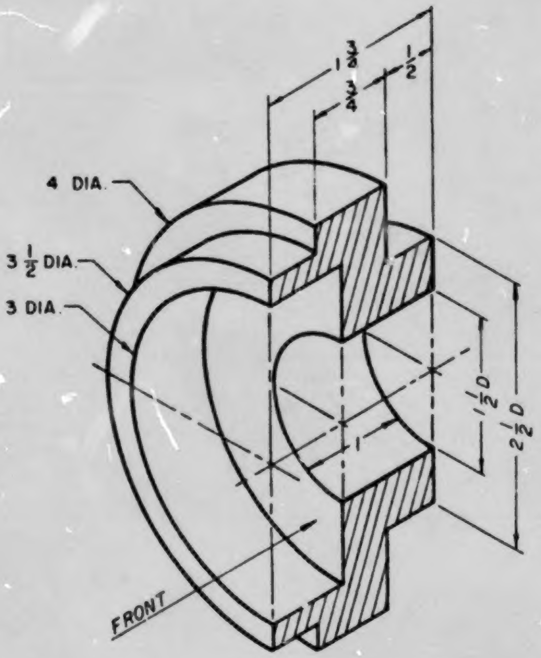
PROBLEM 13-12 Make a full size working sketch of this bracket.


3 7/8
1 1/4
2 1/2
2 1/2
1
3/4
1 3/8 REAM
3/8
4
5/8
DRILL FOR
1/8 OIL HOLE
SHAFT SUPPORT

PROBLEM 13-13 Make a three-view or working drawing of this support.

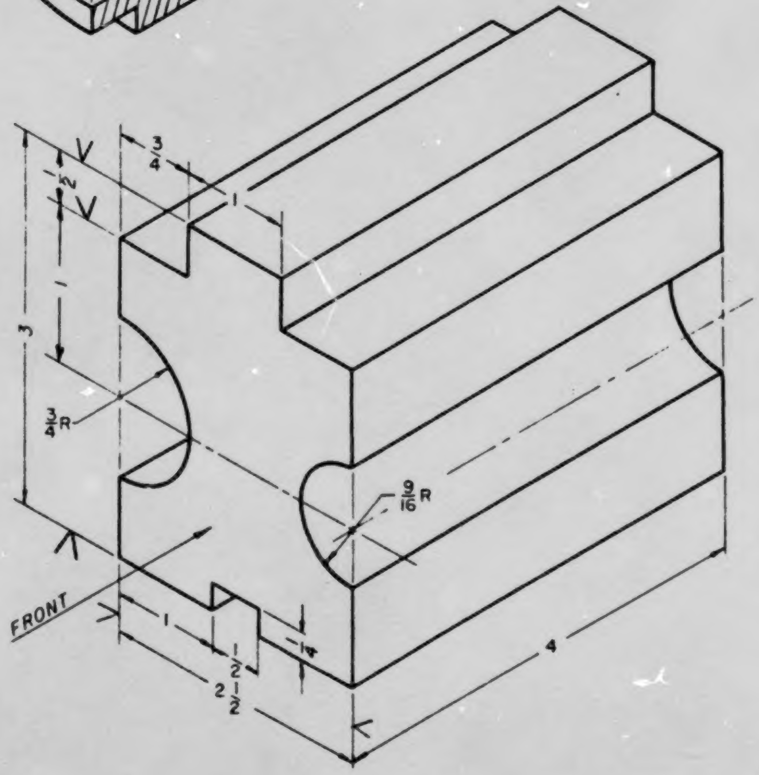
PROBLEM 13-14

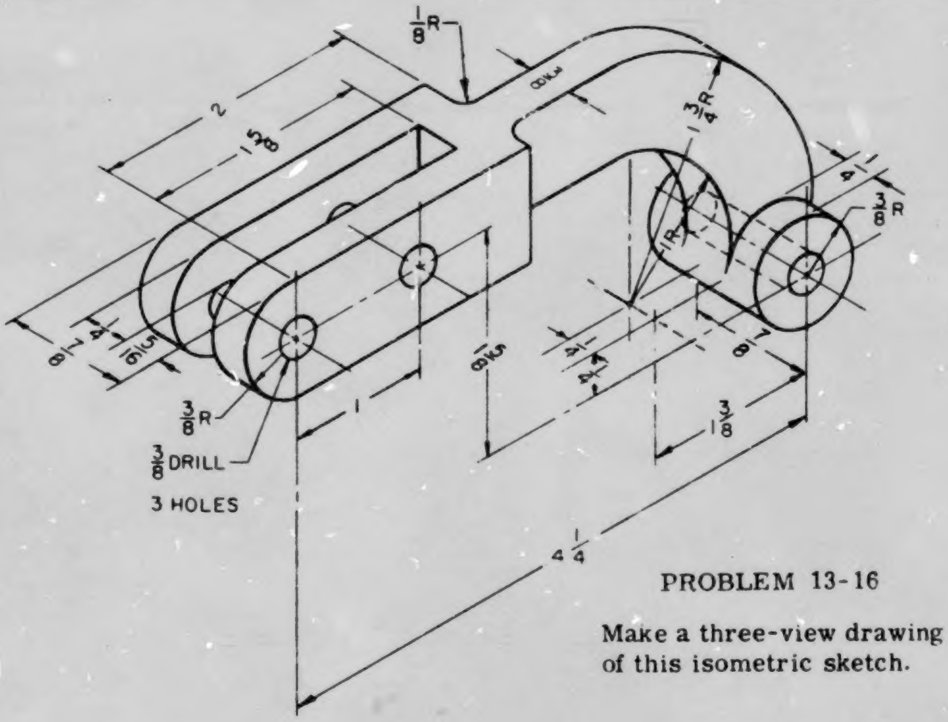
Draw the front, top and right-side views.


1 3/4
1/2
3/4
4 DIA.
3 1/2 DIA.
3 DIA.
1 1/2 D
2 1/2 D
1
FRONT

PROBLEM 13-15

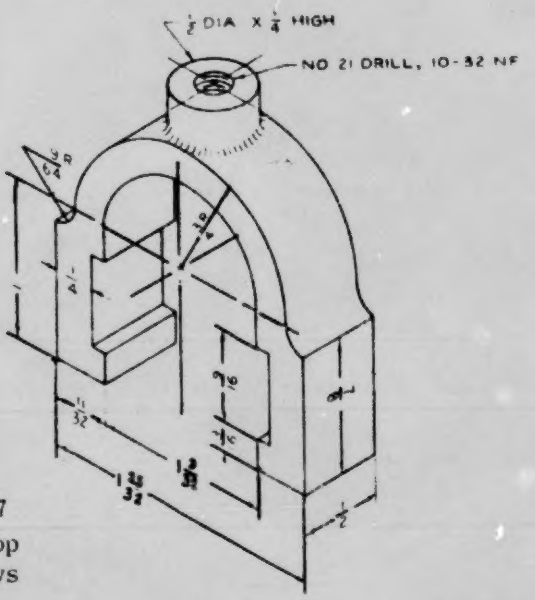
Draw the front, top and right-side views.


3/4
1/2
1
1
3
3/4 R
9/16 R
FRONT
1
1/2
1/4
2 1/2
4


1/8 R
2
1 5/8
3/8
1 3/4 R
1/4
3/8 R
1 R
1/8
1/4
5/16
5/8
1/2
1/4
1/8
3/8 R
3/8 DRILL
3 HOLES
1
1 3/8
4 1/4

PROBLEM 13-16

Make a three-view drawing of this isometric sketch.


1/2 DIA X 1/4 HIGH
NO 21 DRILL, 10-32 NF
9/64 R
3/4 R
1/4
1
9/16
1/16
3/4
11/32
1 3/32
1 25/32
1/2

PROBLEM 13-17

Draw the front, top and left-side views to full scale.

SECTION V PICTORIAL DRAWINGS

Unit 14 ISOMETRIC PICTORIAL DRAWINGS

The three-view drawings already made and studied in this course, although giving all the information a mechanic would need to make the part shown, do not present an actual picture of the part. If it is very complicated, one must sometimes study a three-view drawing quite a while before he can form a mental picture of what it represents.

Pictorial drawings present a picture. They show in one view the length, breadth and thickness, and a single glance will tell what a part should look like when it is made.

There are three kinds of pictorial drawings in common use: Isometric, Oblique and Perspective. The first two are of some value to the mechanic, especially when freehand sketches of simple parts are to be made quickly.

If you place a part whose edges are all straight lines and whose corners are all square corners in a square position in front of you, you will note that there are only three possible directions that straight lines can run, straight up and down, straight across, and straight away, and you will also notice that each corner is made by three edges or lines coming together. These three directions are called isometric axes and are shown below, (Fig. 14-1).

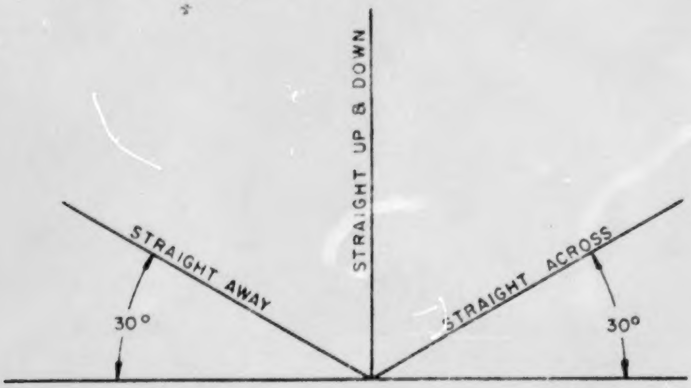


Fig. 14-1

Underlay sheets which have heavy lines 1/4" apart and running in three directions (Fig. 14-2), are used to make isometric sketching easier and more rapid.

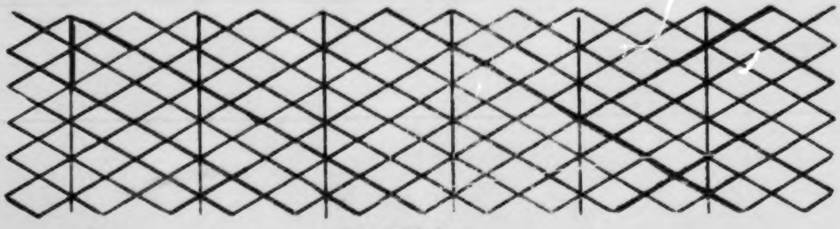


Fig. 14-2

To draw a part having only straight edges and square corners like the one shown in the three-view drawing below (Fig. 14-3), is comparatively simple.

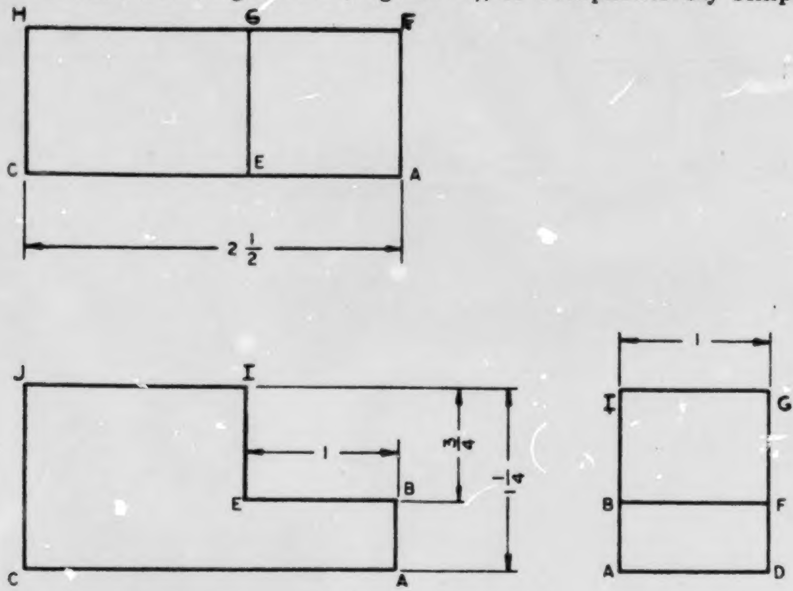


Fig. 14-3

Start at the corner A.

First note the directions and lengths of the three edges forming the corner A as they would appear on the actual block if it were in front of you.

They are: AC, 2 1/2" straight away
AB, 1/2" straight up and down
AD, 1" straight across

(Remember that AD in Fig. 14-3, although running in the same direction as AB, is not an up and down edge on the block.)

Put a sheet of white paper over your 8 1/2 × 11 isometric underlay sheet (see Fig. 14-2) and draw the three lines AC, AB and AD as in Fig. 14-4.

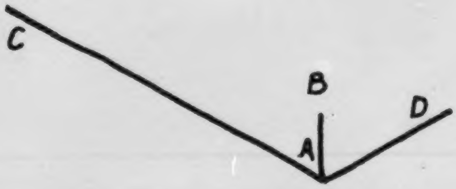


Fig. 14-4

Now the corner A is done.

Next, finish the corner at B by drawing BE and BF. The edge AB has already been drawn. Now the corner B is finished.

Any one of the corners C, D, E or F can be drawn next and, in finishing these corners, other corners may be started.

When all twelve corners of the block are completed, the finished drawing will look like Fig. 14-5 below.

Note that visible edges are represented by heavy, full lines, and hidden or invisible edges by lines made up of heavy short dashes. Dotted lines are sometimes omitted in an isometric sketch unless the object is complicated and difficult to understand without the dotted lines.

Note also that a dimension line takes the same direction as the edge of the block which it measures.

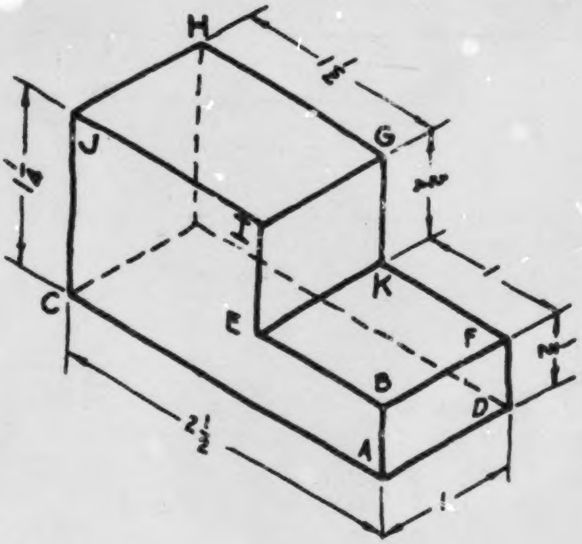


Fig. 14-5

To make an isometric drawing of a triangular block (Fig. 14-6), proceed as follows:

Start at corner A. The three lines which form the corner at A are AB, AC and AD.

AB and AC are not oblique lines and are drawn as already noted on page 110.

Note that AD and CD are shown unequal in length, although the two edges are of equal length on the actual block. Note, also, that AD and CD are not dimensioned directly, but that there are two dimensions given (7/8" and 1 1/2") that tell exactly where lines end. Finding the length of AD or CD is a mathematical problem involving square root or trigonometry.

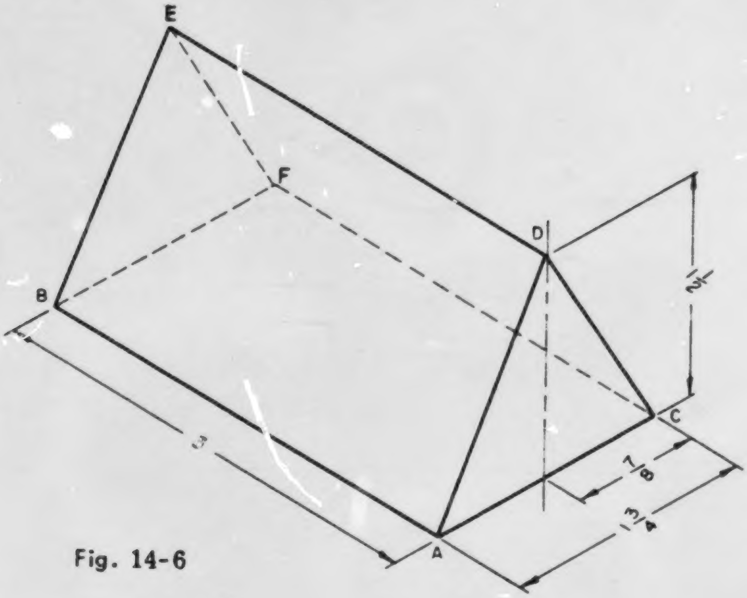


Fig. 14-6

AD is oblique and it cannot be drawn correctly until corner D is located. By studying sketch below (Fig. 14-7), it can easily be seen that D is 1 1/2" straight up from the center point of AC.

Oblique edges are edges that do not run in one of the three square directions, straight up and down, straight away, straight across, or in the plane of the paper, which were explained on page 108. Oblique lines cannot be scaled in isometric drawings. Sometimes, they are longer than their true length, sometimes shorter, but we can locate the two ends of any oblique edge by laying off two square distances. When we know the location of the two ends of a straight line, our problem of drawing the line is solved.

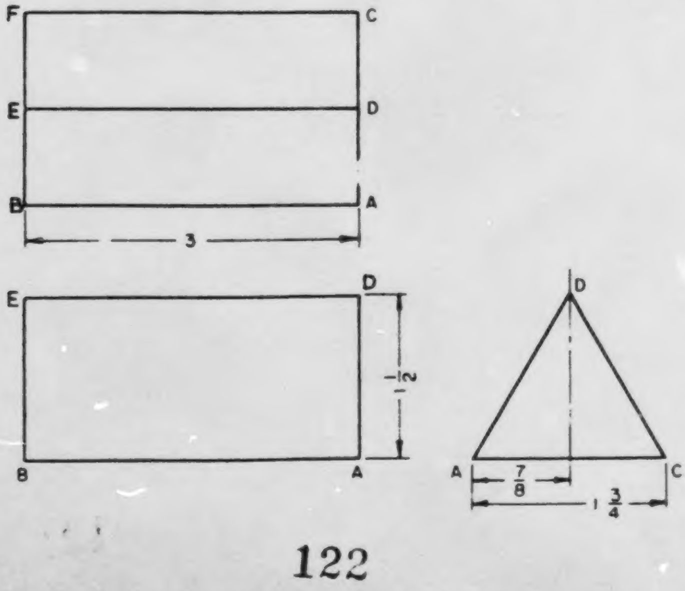
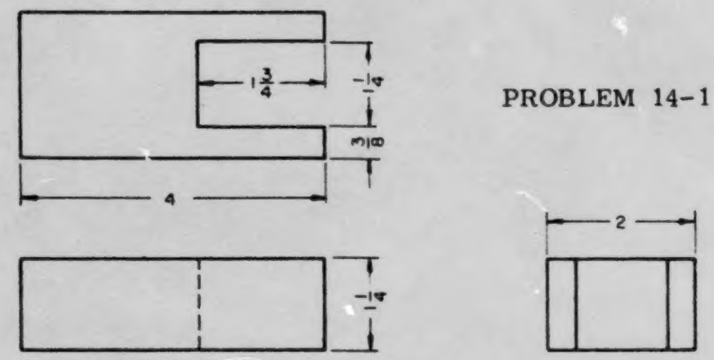


Fig. 14-7

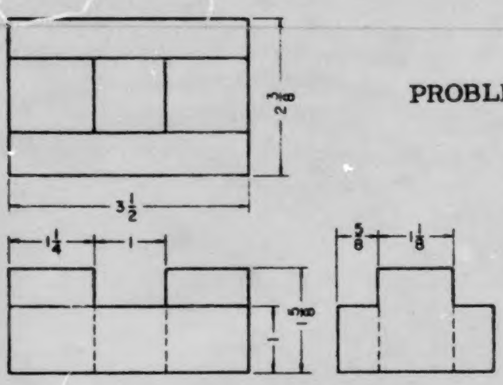
ASSIGNMENT

Prepare drawings (Problems 14-1 through 14-12), following instructions given.

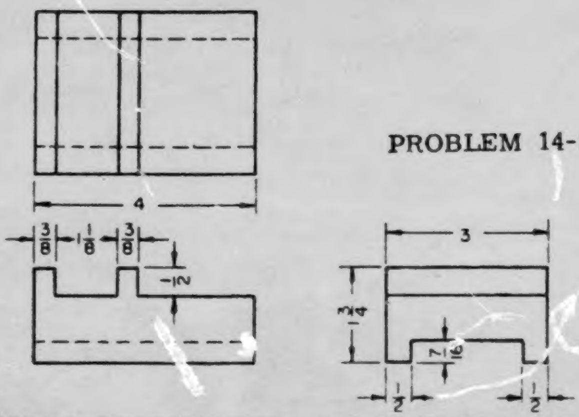
Make full size, isometric drawings of the three-view sketches below, showing all dimensions.


1 3/4
1/4
3/8
4
2
1/4

PROBLEM 14-1

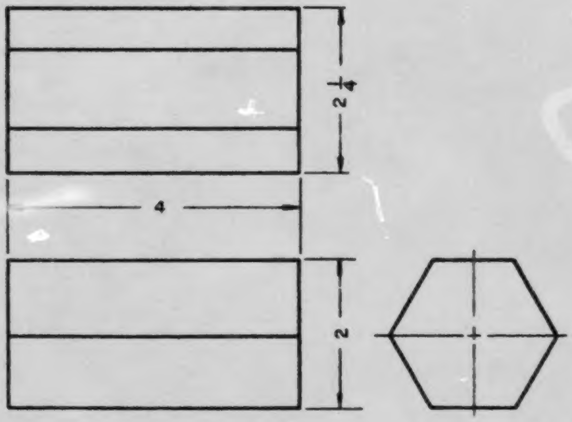

2 3/8
3 1/2
1 1/4
1
1
1 5/8
5/8
1 1/8

PROBLEM 14-2

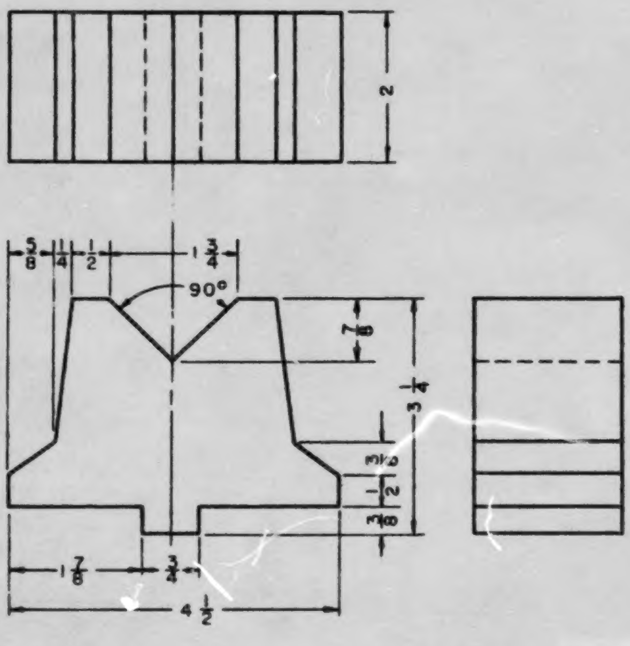

4
3/8
1 1/8
3/8
1/2
3
1 3/4
7/16
1/2
1/2

PROBLEM 14-3

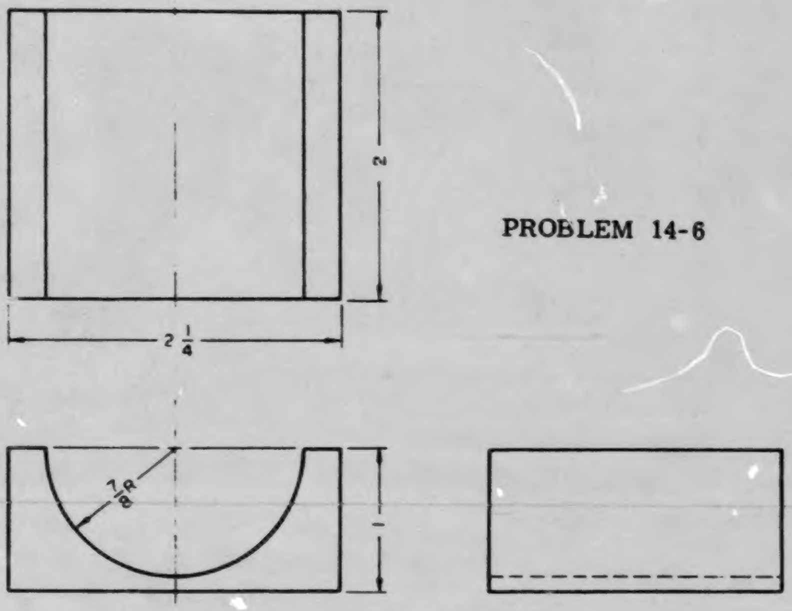
PROBLEM 14-4 Make a full size isometric drawing, with dimensions, of this hexagonal block.



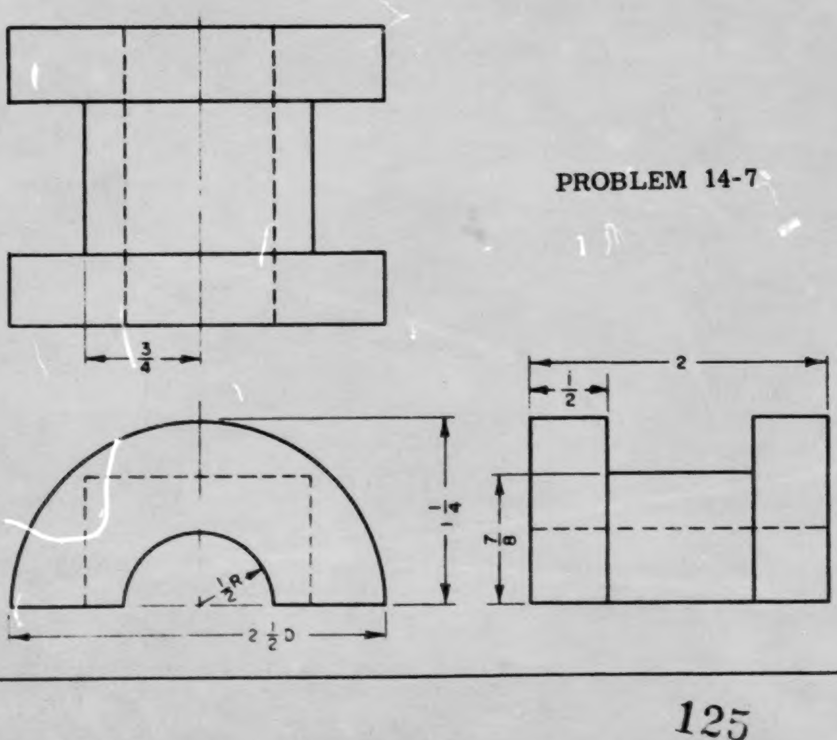
PROBLEM 14-5 Make a full size isometric drawing, with dimensions, of this V-block.


2
5/8
1/4
1/2
1 3/4
90°
7/8
3 1/4
3/8
1/2
3/8
1 7/8
3/4
4 1/2

Make full size, isometric drawings of the three-view sketches below, showing all dimensions



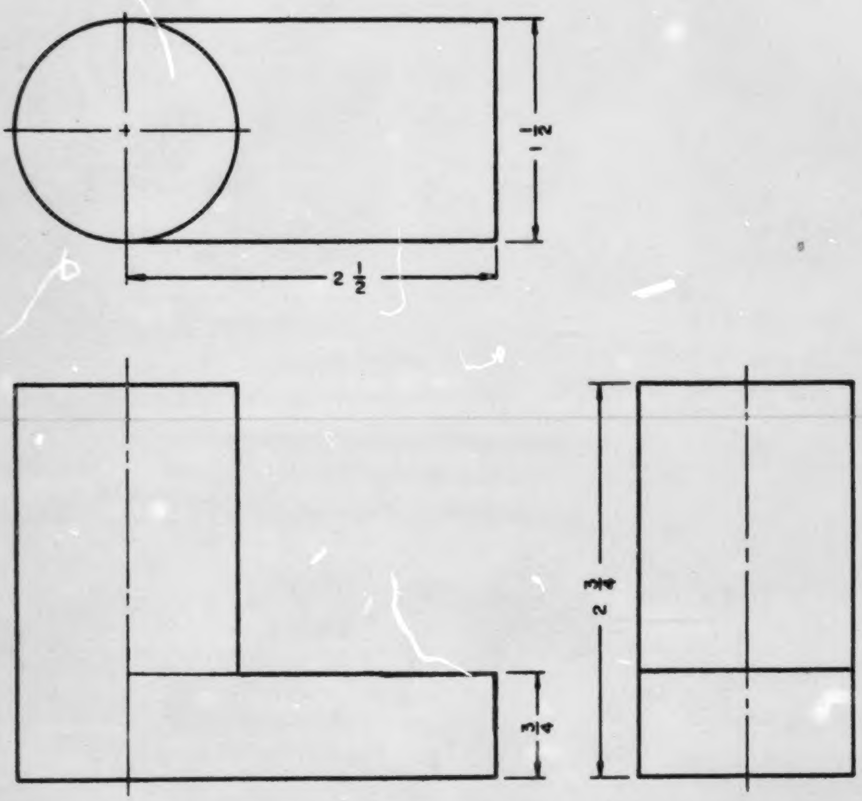
PROBLEM 14-6


3/4
2
1/2
1 1/4
7/8
1/2 R
2 1/2 D

PROBLEM 14-7

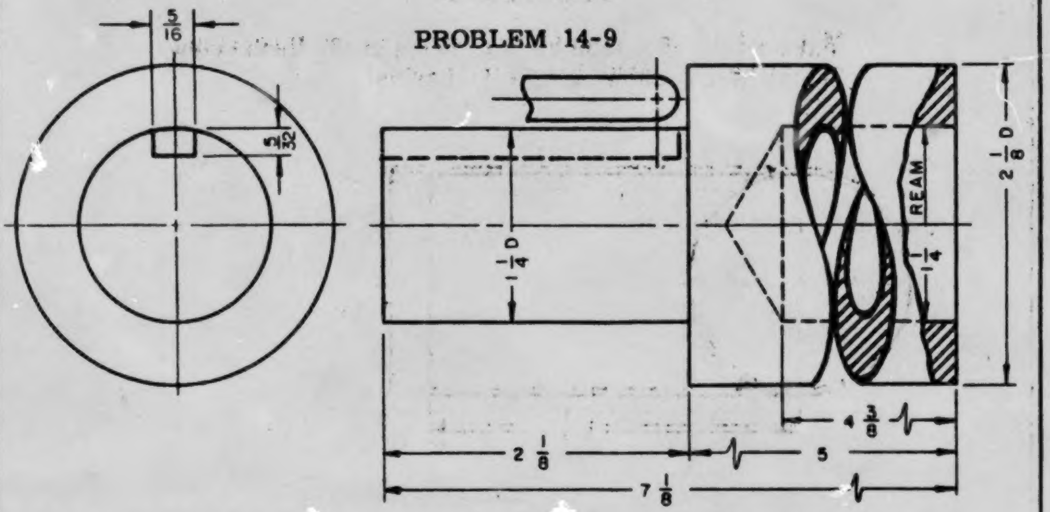
PROBLEM 14-8

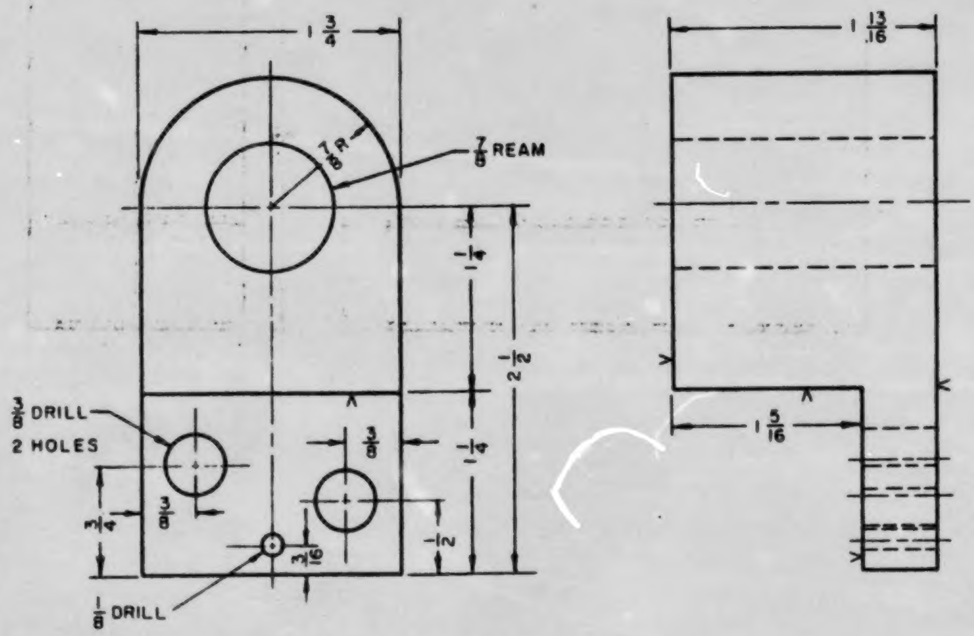
Make a full size, isometric drawing of the three-view sketch below, showing all dimensions.



Make full size, isometric drawings of the two-view sketches below, showing all dimensions.

PROBLEM 14-9

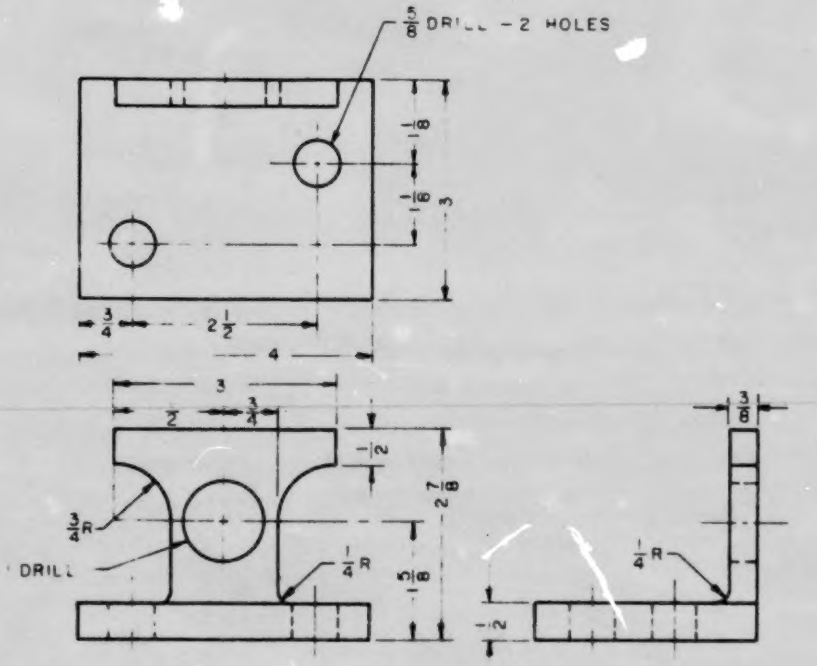

5/16
5/32
1 1/4 D
2 1/8 D
REAM
1 1/4
4 3/8
2 1/8
5
7 1/8


1 3/4
7/8 R
7/8 REAM
1 1/4
2 1/2
1 1/4
3/8 DRILL
2 HOLES
3/8
3/4
3/8
3/16
1/2
1/8 DRILL
1 13/16
1 5/16

PROBLEM 14-10

PROBLEM 14-11

Make a full size isometric drawing of the three-view sketch below, showing all dimensions.


5/8 DRILL - 2 HOLES
1 1/8
1 1/8
3
3/4
2 1/2
4
3
2
3/4
1/2
2 7/8
3/4 R
DRILL
1/4 R
1 5/8
3/8
1/4 R
1/2

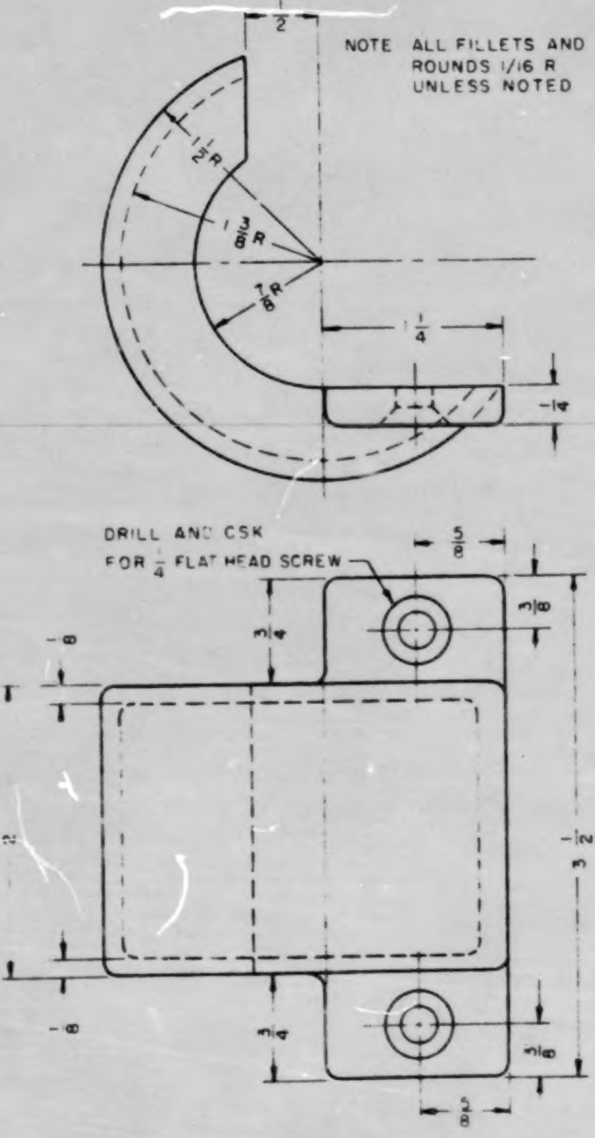
ANGLE BRACKET

NOTE: There are two circles 5/8" in diameter in the top face position, one circle 1" in diameter in the front face position, and two quarter circles having a 3/4 radius in the front face.

Refer to page 5 for the directions that the isometric circles will take for these two faces. Before sketching the circles, the sketch must be far enough along so the centers of each circle can be accurately marked.

PROBLEM 14-12

Make a full size isometric drawing of the two-view sketch below, showing all dimensions.


1/2
NOTE ALL FILLETS AND ROUNDS 1/16 R UNLESS NOTED
1 1/2 R
1 3/8 R
7/8 R
1 1/4
1/4
DRILL AND CSK FOR 1/4 FLAT HEAD SCREW
5/8
3/8
3/4
1/8
2
1/8
3/4
3/8
5/8
3 1/2

Unit 15 OBLIQUE PICTORIAL DRAWINGS

Oblique projection, often called "cabinet projection," shows the front of a part or an object exactly the same as the front view of a three-view sketch. The front face is dimensioned for height and width. As in a three-view sketch, the lines denoting length run back at any convenient angle and go up or down, to the right or left, according to the picture the draftsman wishes to show.

OBLIQUE PROJECTION OF CIRCLES

If a circle is in the front face of an oblique projection, it is drawn as a true circle. If it is on one of the faces that runs back, it is drawn by blocking in the lines of the square that would enclose the circle and then sketching an ellipse through the mid-points of its sides.

ASSIGNMENT

Prepare drawings (Problems 15-1 through 15-12), following instructions given.

Make full size oblique drawings of the parts shown in Problems 14-1 through 14-12. Use oblique projections A through D, for reference as shown below, (Fig. 15-1).

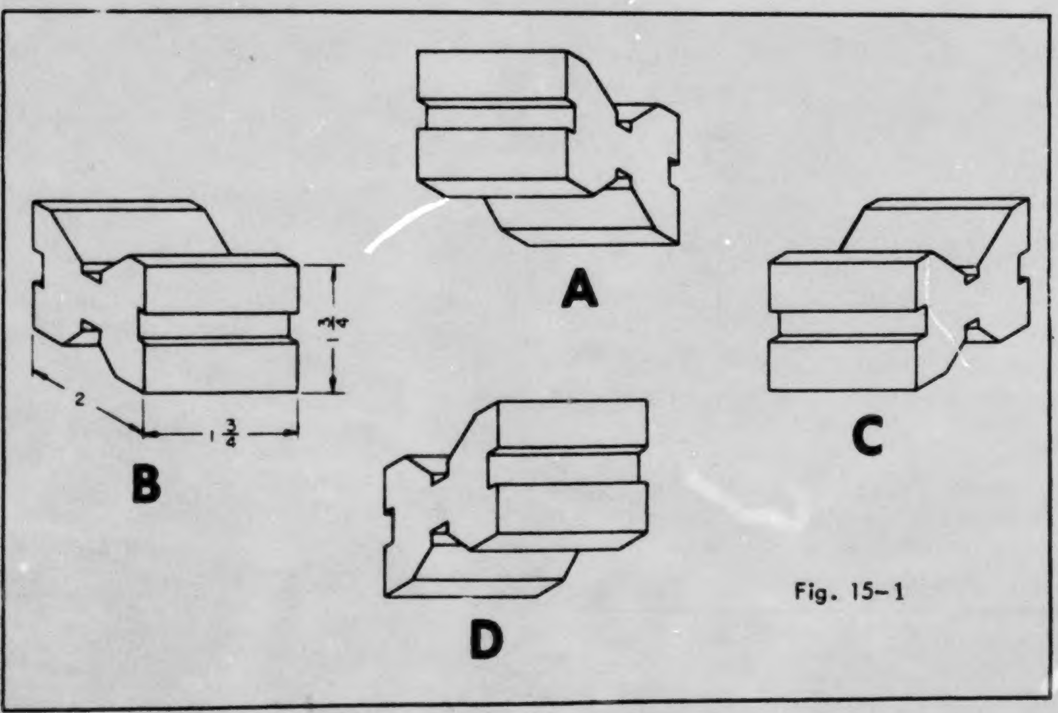


Fig. 15-1

SECTION VI *SECTIONAL REPRESENTATIONS*

Unit 16 SECTIONAL VIEWS

A sectional view is what is seen if a part of the object has been cut away and removed. It is used to show the interior construction and other information not shown in the regular two or three view drawings.

The path which the cut takes in cutting away a part of the object is known as the "cutting plane," and is indicated by a broken line of one long and two short dashes (———— – – ———— – – ————) called a section line or a reference line. (See Fig. 16-1, line A-A) The arrows at the end indicate the direction in which the section is viewed. It is not necessary for the cutting plane to be in a straight continuous line; it may be bent or offset.

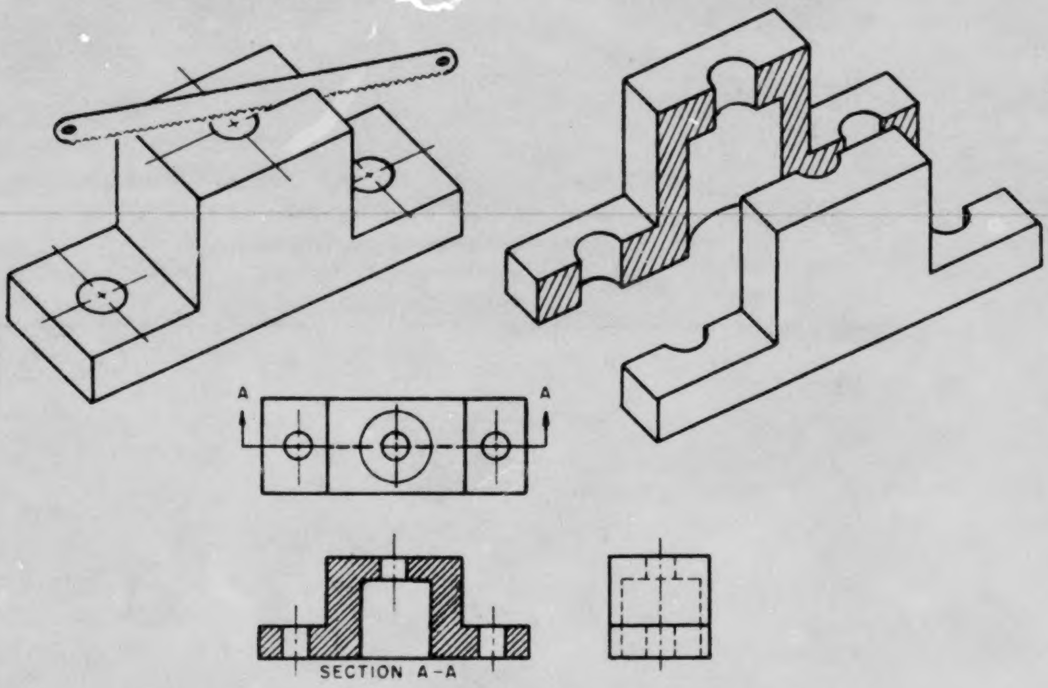
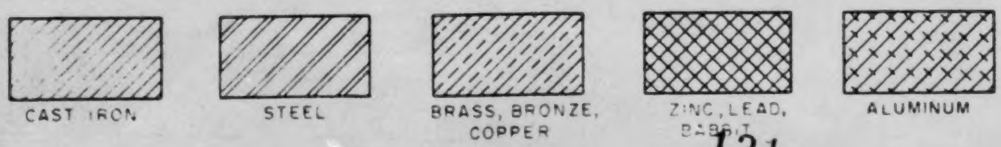


Fig. 16-1

All surfaces which have been cut are indicated by section lining or cross-hatching. These lines are usually drawn at 45 degrees and are light parallel lines. Different combinations of these lines tell what material the part is made of. Some of the most common of these combinations are:



- Sectional views very seldom show any hidden edges.
- Sectional lines are never drawn parallel to object lines of the part cut.
- Sectional views show all visible detail behind the cutting plane.
- Sectional views are classified as full sections, half sections, revolved sections. removed sections, broken-out sections, offset sections, aligned sections and assembly sections.

FULL SECTIONS

A full section is a view obtained when the cutting plane passes the center of the object. The position of the cutting plane is normally along the main axis, but it may be offset to clarify the important interior details not shown along the centerline, (Fig. 16-2).

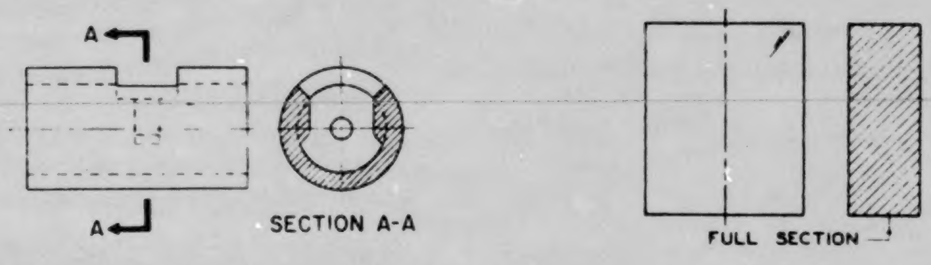


Fig. 16-2

HALF SECTIONS

A half section is a view of a symmetrical object that shows the internal and external detail. The cutting planes pass at right angles to each other along the centerlines or symmetrical axes. Thus, one quarter of the object is considered removed and the interior is exposed to the view, (Fig. 16-3).

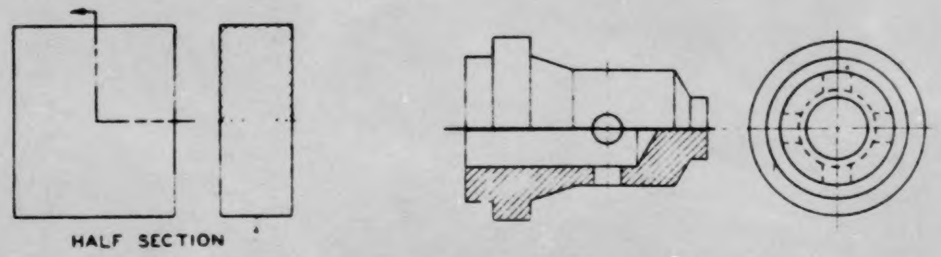


Fig. 16-3

REVOLVED SECTIONS

A revolved section shows the cross section at the point of rotation as shown in Fig. 16-4. The cutting plane passes through the object perpendicular to the centerline.

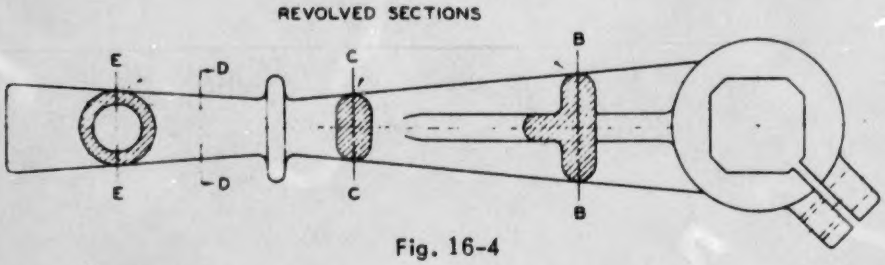


Fig. 16-4

REMOVED SECTIONS

Removed sections are similar to revolved sections. The difference between the two types is that the revolved section removes the section from the object and locates the section in a suitable place to eliminate overcrowding on the view, (Fig. 16-5).

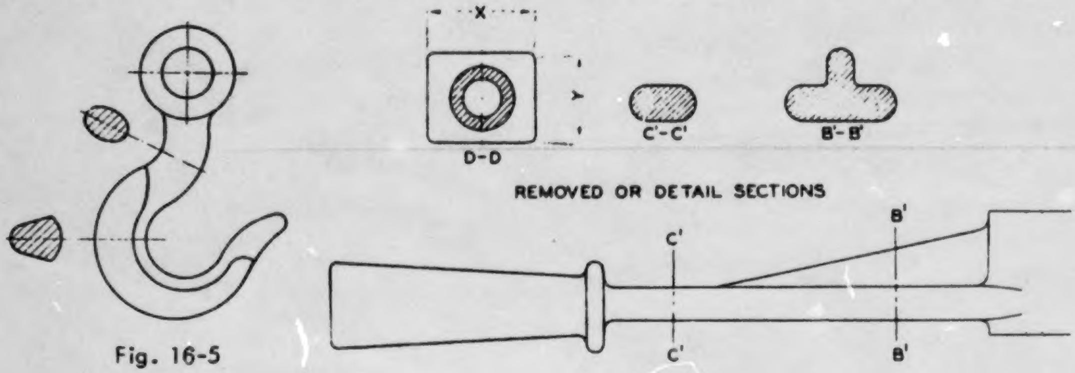


Fig. 16-5

BROKEN-OUT SECTIONS

The purpose of a broken-out section is to clarify an interior detail and to dimension a section, see Fig. 16-6. Broken-out sections are used when a half or full section would remove important exterior detail.

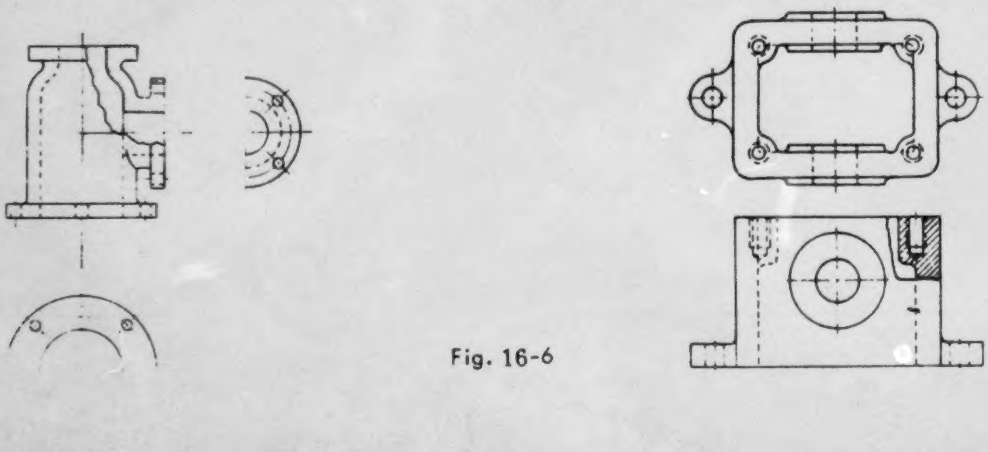


Fig. 16-6

OFFSET SECTIONS

The offset section is used to pass a cutting plane through sections which need clarification. When making an offset sectional view, the offsets are not shown in the sectional view, (Fig. 16-7).

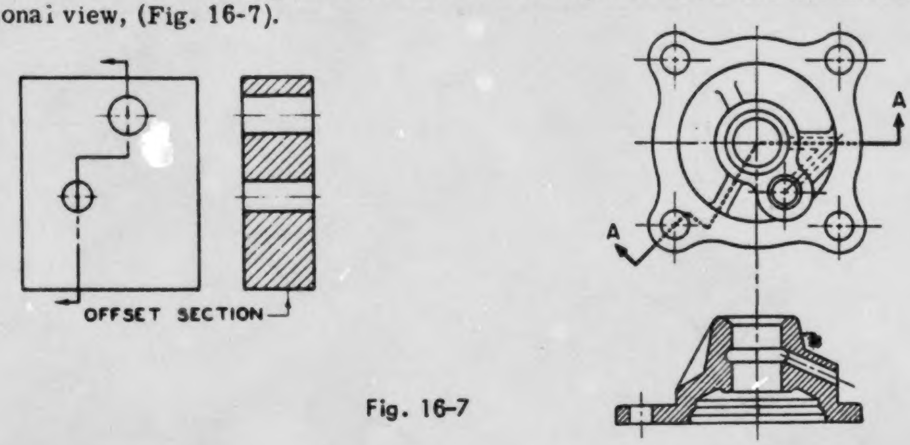


Fig. 16-7

ALIGNED SECTIONS

When the cutting plane does not pass through a rib, web, or similar parallel elements, the part is to be drawn by rotating it into or out of the cutting plane, Fig. 16-8.

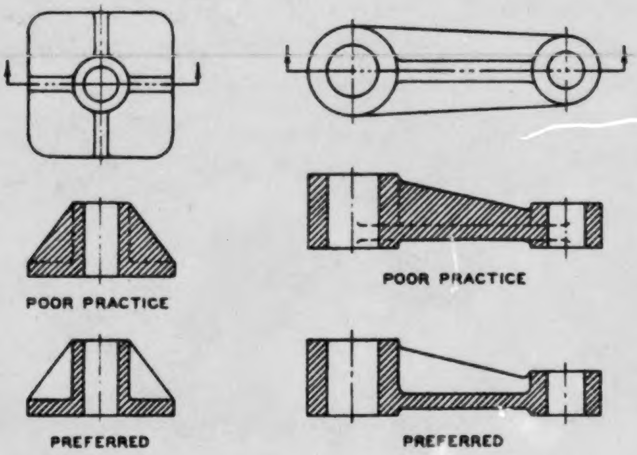


Fig. 16-8

ASSEMBLY SECTIONS

The section of an assembly is required when internal parts or details cannot be shown clearly. Standard parts such as bolts, bearing nuts, gear teeth and webs are not sectioned and the cutting plane does not pass through them, (Fig. 16-9). The material is to be sectioned according to the type.

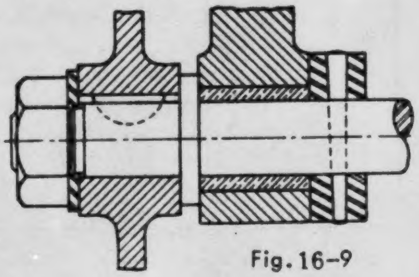


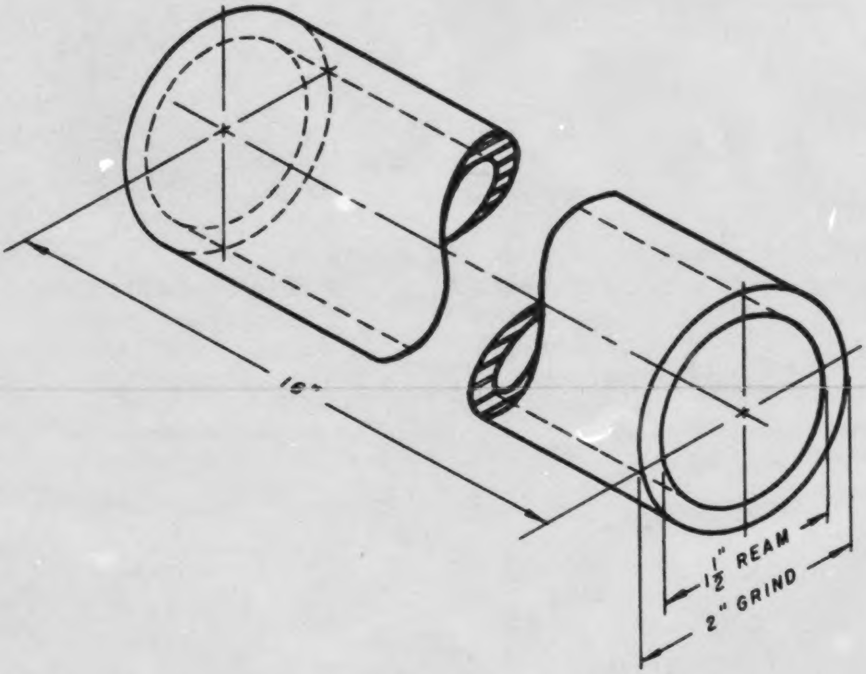
Fig. 16-9

ASSIGNMENT

Prepare drawings (Problems 16-1 through 16-11), following instructions given.

PROBLEM 16-1

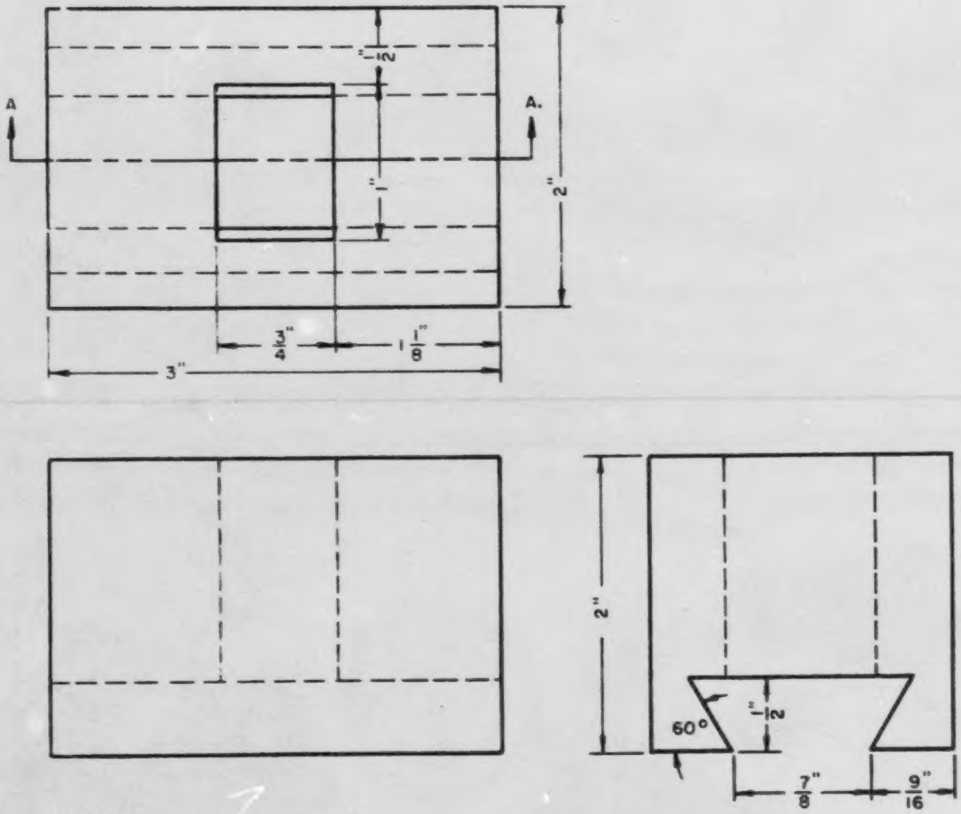
Make a two-view sketch of the part shown below.



This drawing shows a part broken apart near its center. This is called a "conventional section" or "break." Breaks are often used to save space when drawing a long straight object that has a uniform cross section. Notice, however, that the dimensioned length is the full length of the part to be drawn.

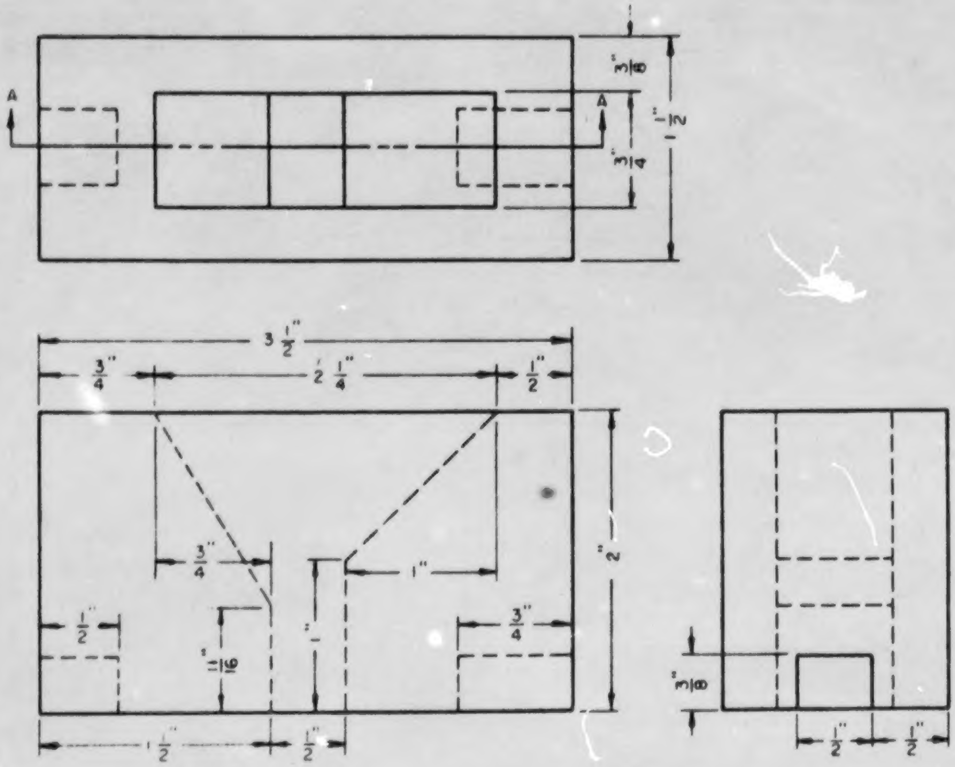
PROBLEM 16-2

Redraw the views shown, changing the proper view to a sectional view according to the reference line A-A. Material: cast iron.


A
A.
1/2"
1"
2"
3/4"
1 1/8"
3"
2"
60°
1/2"
7/8"
9/16"

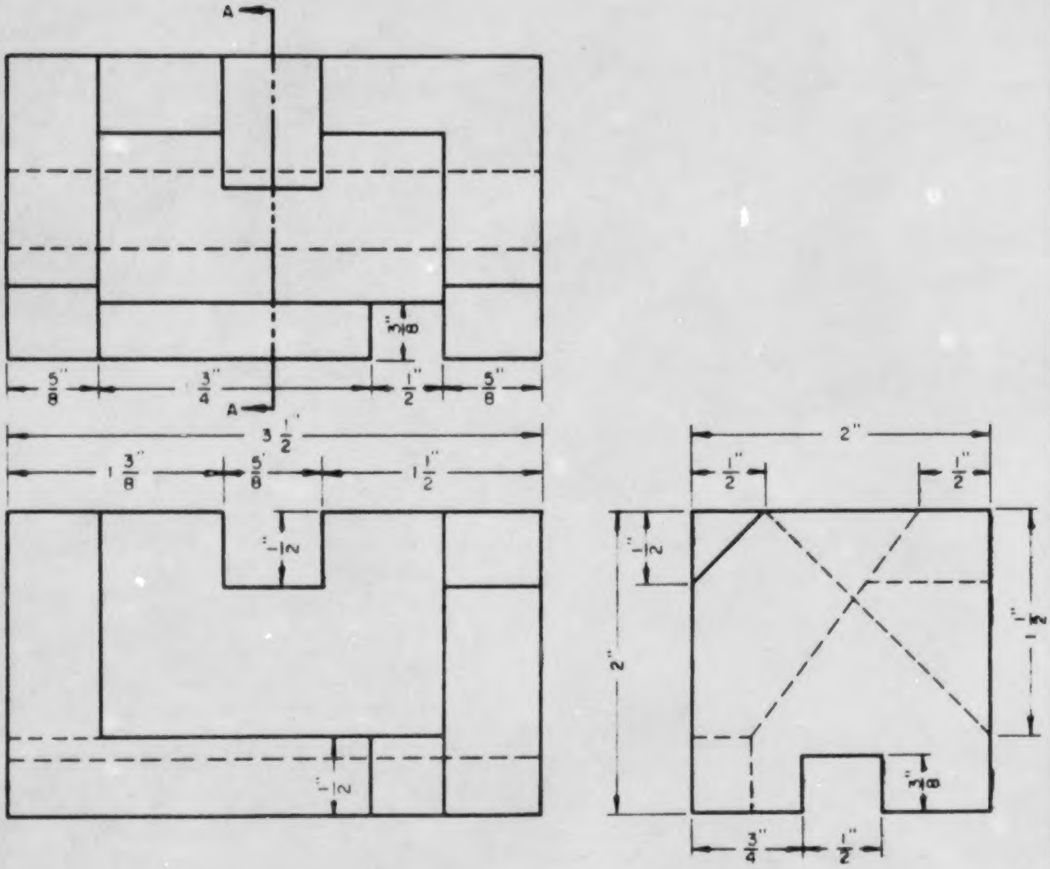
PROBLEM 16-3

Redraw the views below, changing the proper view to a sectional view according to the reference line A-A. Material: brass.


A
A
3/8"
1 1/2"
3/4"
3 1/2"
3/4"
2 1/4"
1/2"
3/4"
1"
2"
1/2"
11/16"
1"
3/4"
1 1/2"
1/2"
3/8"
1/2"
1/2"

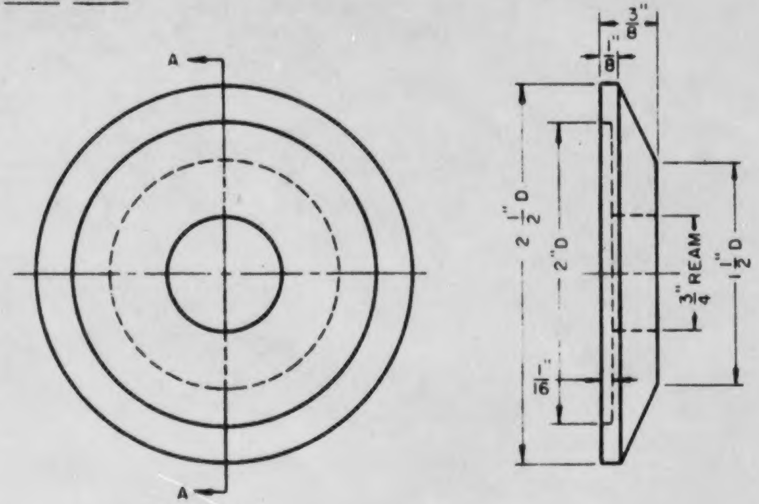
PROBLEM 16-4

Redraw the views below, changing the proper view to a sectional view according to the reference line A-A. Material: aluminum.


A
A
5/8"
3/4"
1/2"
5/8"
3/8"
3 1/2"
1 3/8"
5/8"
1 1/2"
1/2"
1/2"
2"
1/2"
1/2"
1/2"
2"
1 1/2"
3/8"
3/4"
1/2"

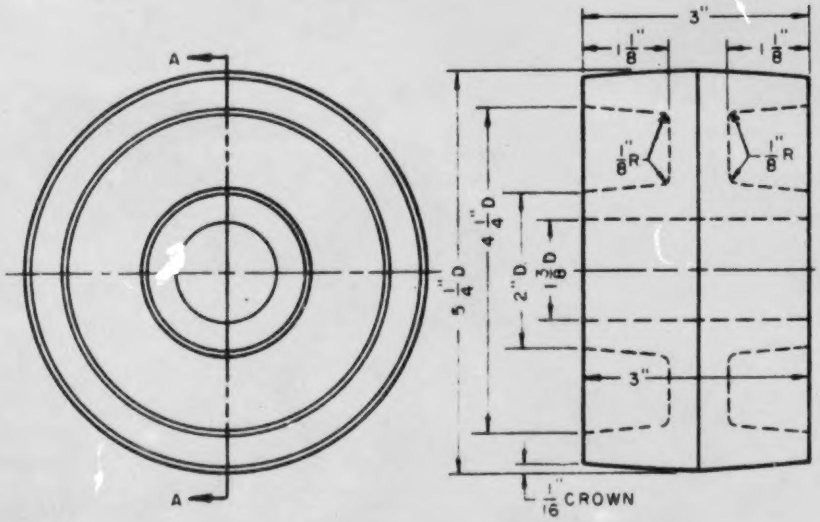
PROBLEM 16-5

Redraw the views below, changing the end or side view into a sectional view according to the reference line A-A. Material: mild steel.


A
A
3/8"
1/8"
2 1/2" D
2" D
1/16"
3/4" REAM
1 1/2" D

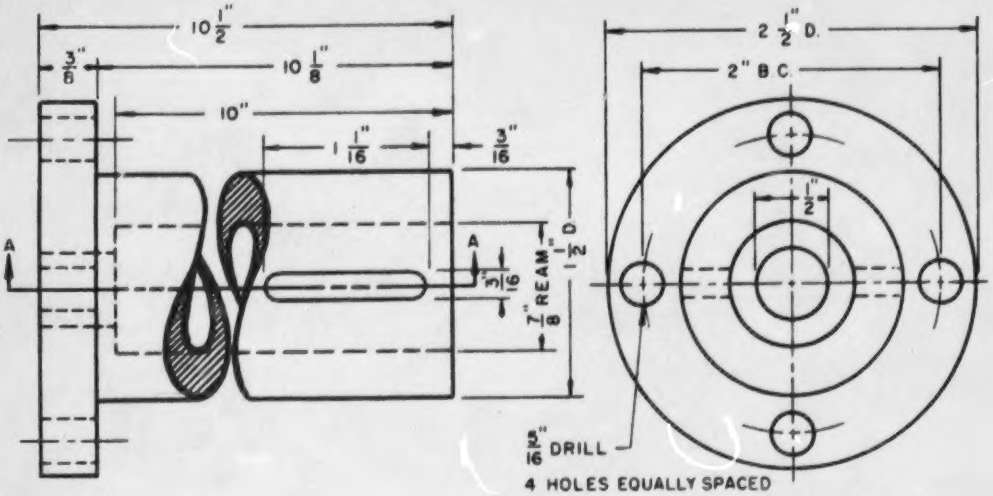
PROBLEM 16-6

Make a two-view, half-size working drawing of the pulley, showing one view in section. Section to be taken on reference line A-A. Material: cast iron.


A
A
3"
1 1/8"
1 1/8"
1/8" R
1/8" R
5 1/4" D
4 1/4" D
2" D
1 3/8" D
3"
1/16" CROWN

PROBLEM 16-7

Make a two-view, working drawing of the Locking Bolt Holder showing the proper section on reference line A-A. Material: steel casting. The sectional view will be in addition to the two regular views shown.

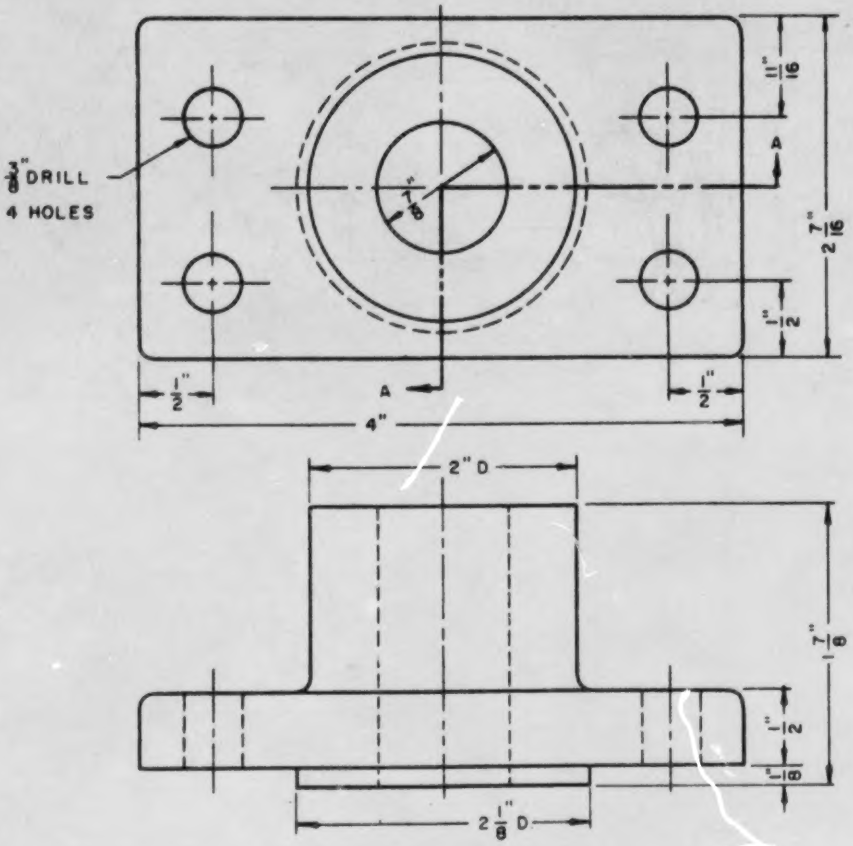

10 1/2"
3/8"
10 1/8"
10"
1 1/16"
3/16"
A
A
3/16"
7/8" REAM
1 1/2" D
2 1/2" D.
2" B C
1/2"
5/16" DRILL
4 HOLES EQUALLY SPACED

B C IS BOLT CIRCLE

PROBLEM 16-8

Make a two-view, working drawing of the Hand Wheel Bracket showing the section in the front view on reference line A-A. Material: cast iron.

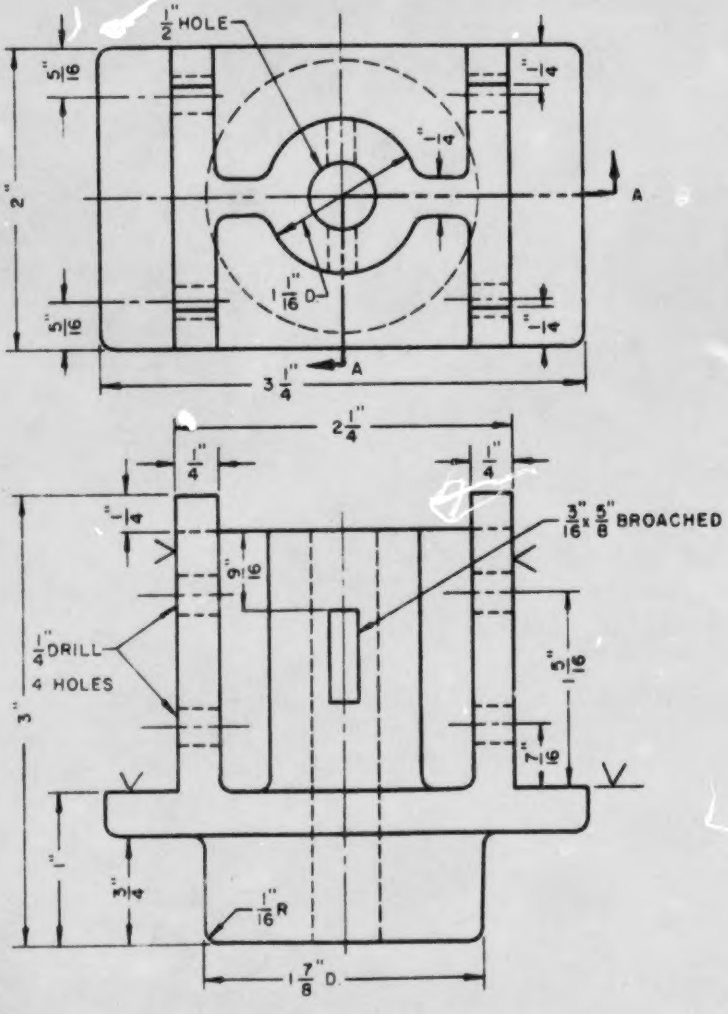
NOTE: ALL FILLETS & ROUNDS $\frac{1}{8}$" R



3/8" DRILL
4 HOLES
7/8"
11/16"
A
2 7/16"
1/2"
1/2"
A
1/2"
4"
2" D
1 7/8"
1/2"
1/8"
2 1/8" D

PROBLEM 16-9

This sketch shows a casting for a truck. It is made of cast iron and finished as shown. Make a three-view working drawing and in the side view, show a section cut on reference line A-A.

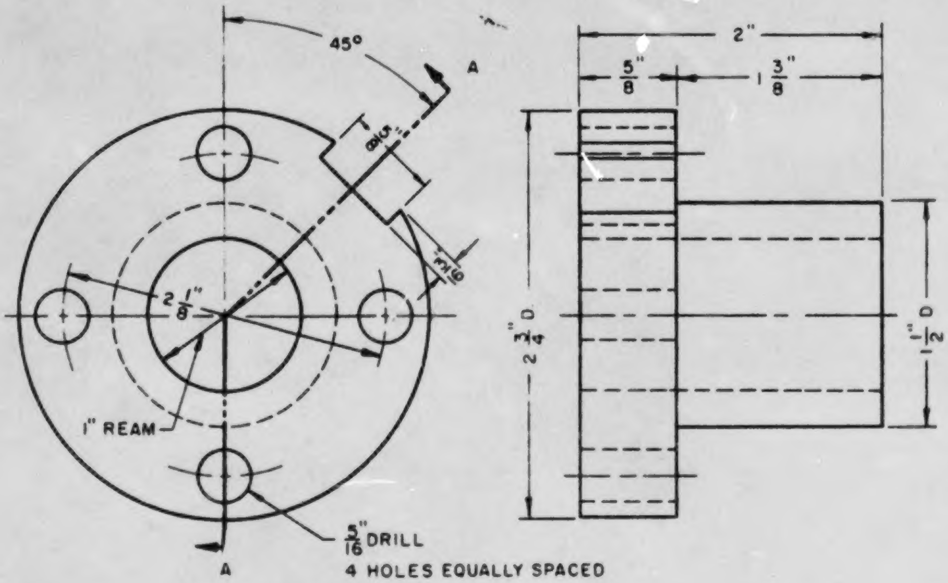

1/2" HOLE
5/16"
1/4"
1/4"
2"
A
1 1/16" D.
5/16"
1/4"
A
3 1/4"
2 1/4"
1/4"
1/4"
1/4"
3/16" x 5/8" BROACHED
9/16"
1/4" DRILL
4 HOLES
1 5/16"
3"
7/16"
1"
3/4"
1/16" R
1 7/8" D.

NOTE: ALL FILLETS AND ROUNDS 1/16 R

PROBLEM 16-10

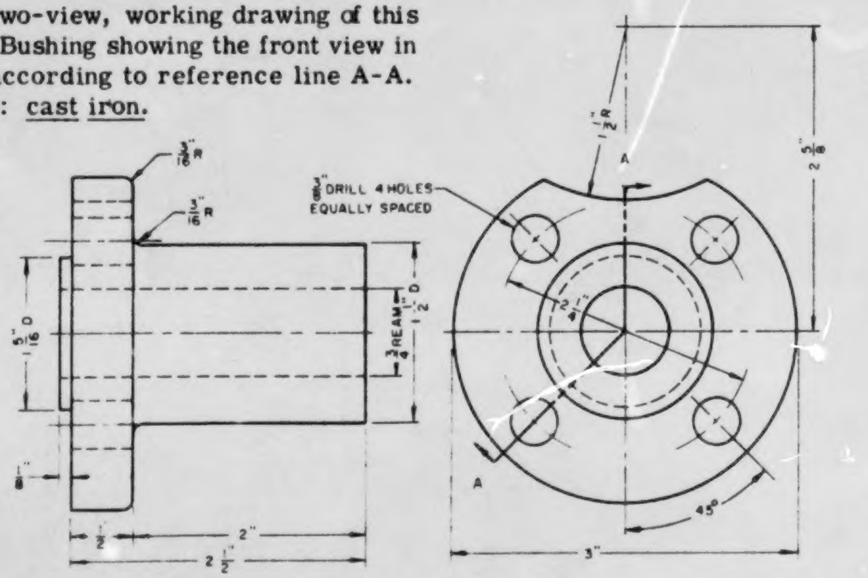
Make a two-view working drawing showing the front view in section according to reference line A-A. Material: bronze.

Reference line A-A is not a straight line. The section will be drawn as if the upper half of A-A was vertical. This is called a bent section.


45°
A
1/4
5/16
2 1/8"
1" REAM
5/16" DRILL
4 HOLES EQUALLY SPACED
A
2"
5/8"
1 3/8"
2 3/4 D
1 1/2" D

PROBLEM 16-11

Make a two-view, working drawing of this Flanged Bushing showing the front view in section according to reference line A-A. Material: cast iron.


3/16"R
3/16"R
1 5/16" D
3/4 REAM
1 1/2" D
1/8"
1/2"
2"
2 1/2"
3/8" DRILL 4 HOLES EQUALLY SPACED
1 1/2 R
A
2 1/4"
2 5/8"
A
45°
3"

Unit 17 AUXILIARY VIEWS

Some objects have slanting surfaces on which various machine operations are performed, such as:

- drilling
- reaming
- counterboring

With objects of this type, none of the regular orthographic views will show a true picture of the slanting surface, and it will be impossible many times to put the necessary information on these views.

An auxiliary view is made of this slanting surface by projecting lines, at right angles, from it.

The dimensions, hole sizes, threads, etc., pertaining to the slanting surface, are placed on the auxiliary view.

The auxiliary view will have hidden edges only when it is necessary to complete the information needed, and it is a view of the slanting surface only, (see Fig. 17-1).

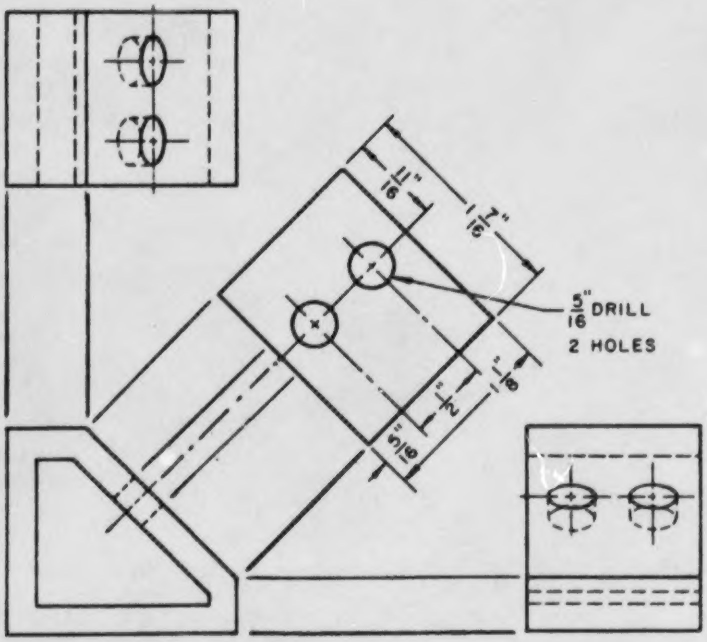


Fig. 17-1

Figs. 17-2 and 17-3 show the three types of primary auxiliary views: front, side and top. A front auxiliary plane is perpendicular to the front vertical plane and inclined to the horizontal and profile planes. The view is a front auxiliary view.

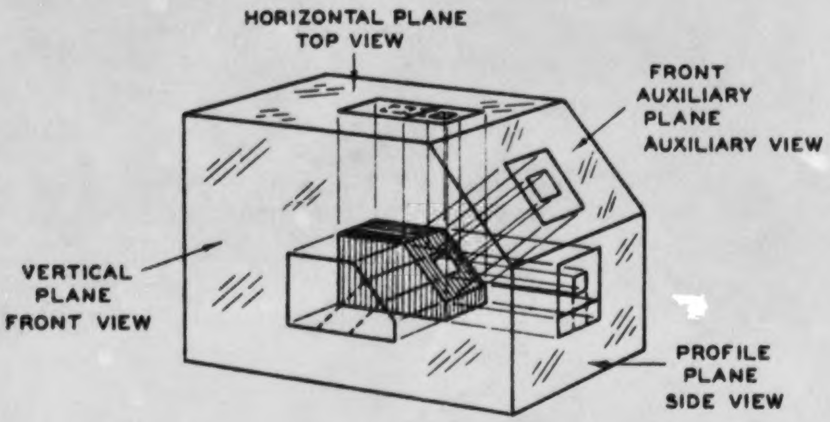

HORIZONTAL PLANE
TOP VIEW
FRONT
AUXILIARY
PLANE
AUXILIARY VIEW
VERTICAL
PLANE
FRONT VIEW
PROFILE
PLANE
SIDE VIEW

Fig. 17-2

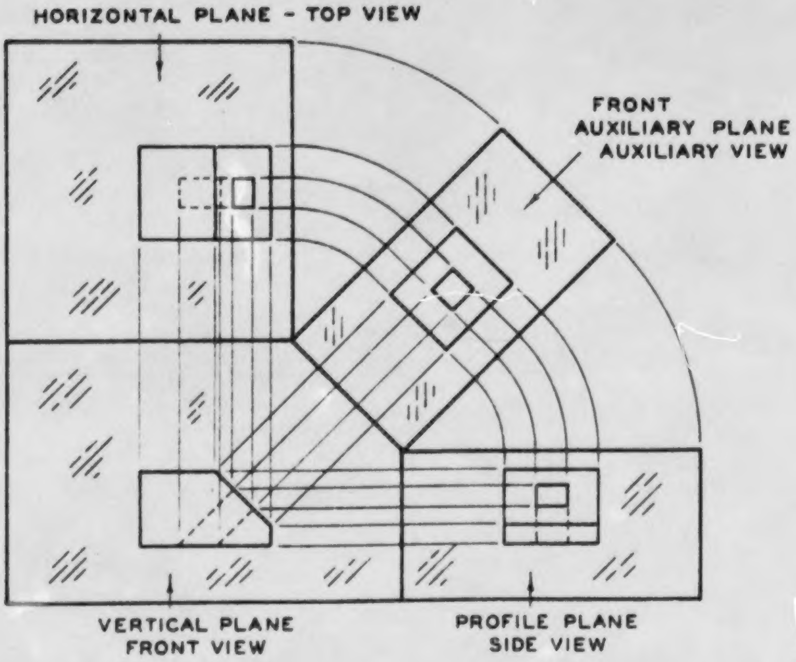

HORIZONTAL PLANE - TOP VIEW
FRONT
AUXILIARY PLANE
AUXILIARY VIEW
VERTICAL PLANE
FRONT VIEW
PROFILE PLANE
SIDE VIEW

Fig. 17-3

A profile auxiliary plane is perpendicular to the profile plane and inclined to the horizontal and front planes. The view of the profile auxiliary plane is a profile auxiliary view. (See Figs. 17-4 and 17-5.)

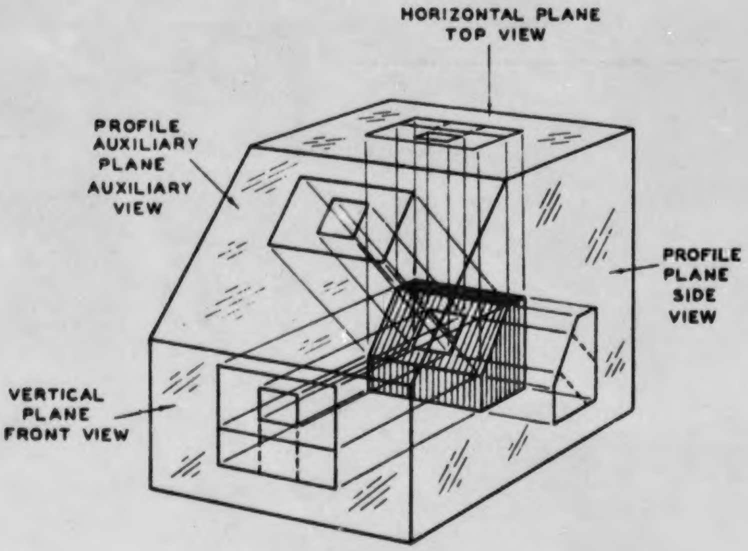

HORIZONTAL PLANE
TOP VIEW
PROFILE
AUXILIARY
PLANE
AUXILIARY
VIEW
PROFILE
PLANE
SIDE
VIEW
VERTICAL
PLANE
FRONT VIEW

Fig. 17-4

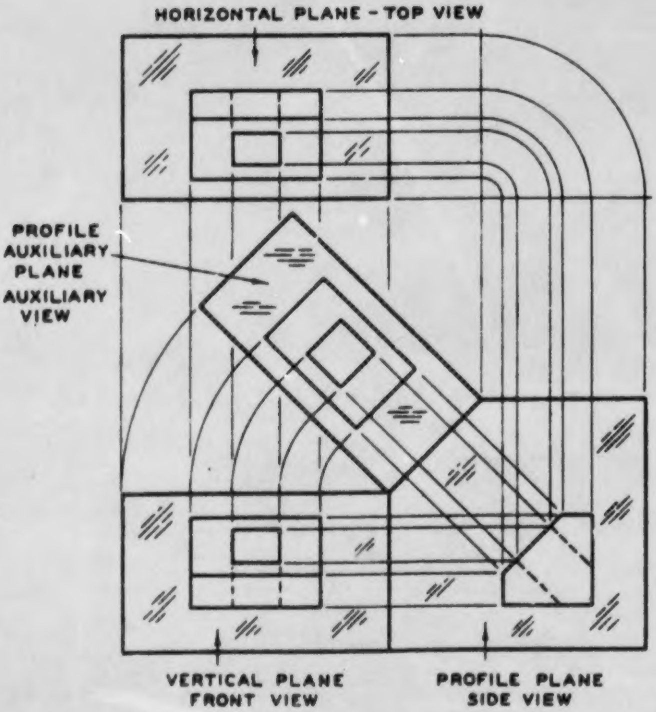

HORIZONTAL PLANE - TOP VIEW
PROFILE
AUXILIARY
PLANE
AUXILIARY
VIEW
VERTICAL PLANE
FRONT VIEW
PROFILE PLANE
SIDE VIEW

Fig. 17-5

An auxiliary plane perpendicular to the top horizontal plane and inclined to the vertical and profile planes is a top auxiliary plane. The view of the top auxiliary plane is a top auxiliary view. (See Figs. 17-6 and 17-7.)

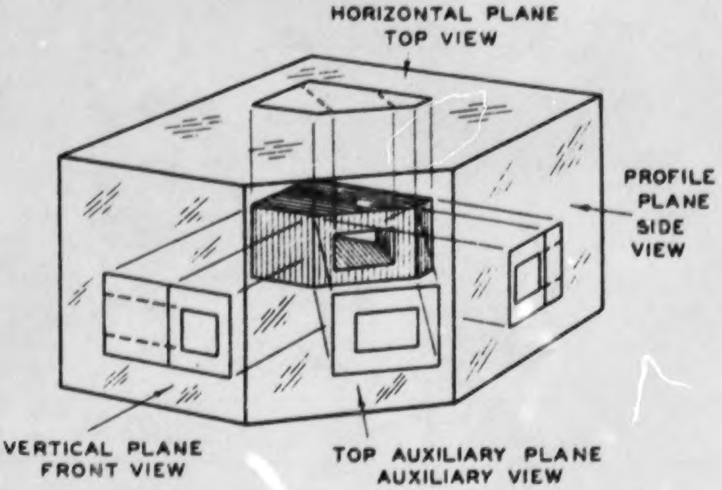

HORIZONTAL PLANE
TOP VIEW
PROFILE PLANE SIDE VIEW
VERTICAL PLANE FRONT VIEW
TOP AUXILIARY PLANE AUXILIARY VIEW

Fig. 17-6

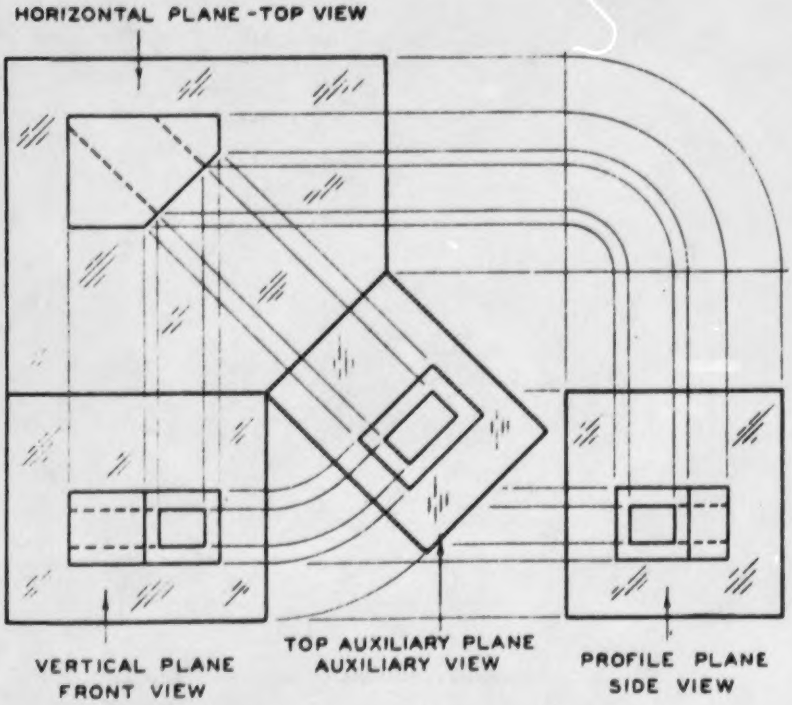

HORIZONTAL PLANE - TOP VIEW
VERTICAL PLANE FRONT VIEW
TOP AUXILIARY PLANE AUXILIARY VIEW
PROFILE PLANE SIDE VIEW

Fig. 17-7

SECONDARY AUXILIARY VIEWS

A secondary auxiliary view is an oblique surface inclined to all three principal projection planes. It is not an edge view in any principal view. (See Fig. 17-8.)

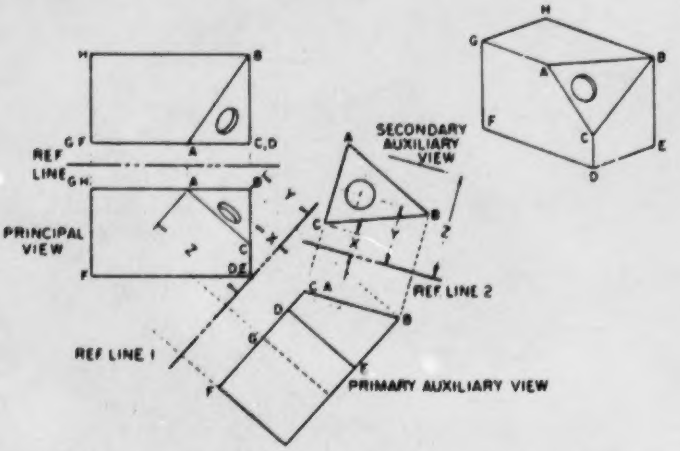

H
B
G F
REF LINE
C,D
A
G H
A
B
PRINCIPAL VIEW
C
D E
F
SECONDARY AUXILIARY VIEW
A
C
B
X
Y
Z
REF LINE 2
C A
D
B
G
REF LINE 1
F
E
PRIMARY AUXILIARY VIEW
H
G
B
A
F
C
E
D

Fig. 17-8

An oblique surface projects as an edge view only in the single auxiliary view. Its true view is then projected into the secondary auxiliary view, Fig. 17-8. A single auxiliary view is always projected at an angle from a principal view and a secondary auxiliary view is always projected from the primary view.

The number of views required for secondary auxiliary views are either two principal views, a primary view and an auxiliary view or three principal views, a primary view and an auxiliary view.

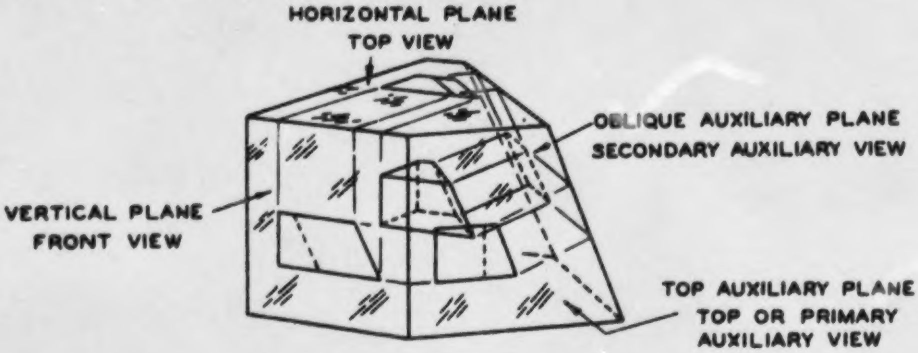
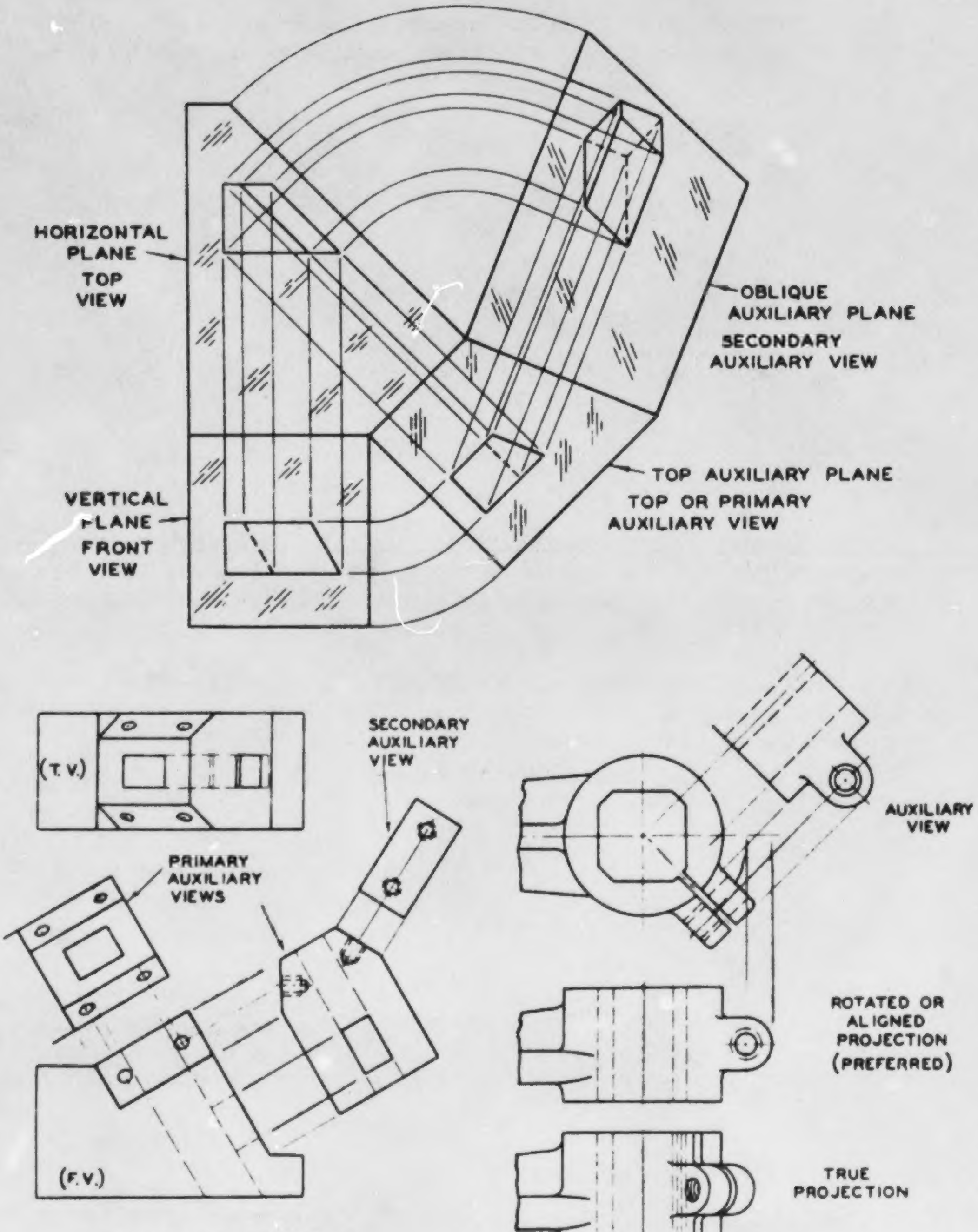

HORIZONTAL PLANE
TOP VIEW
OBLIQUE AUXILIARY PLANE
SECONDARY AUXILIARY VIEW
VERTICAL PLANE
FRONT VIEW
TOP AUXILIARY PLANE
TOP OR PRIMARY
AUXILIARY VIEW

Fig. 17-9

OBLIQUE AUXILIARY VIEWS

In Fig. 17-9, an object is shown suspended within a transparent box. One surface of this object is inclined to all of the principal planes and perpendicular to none. A surface which is inclined to all of the principal planes is called an oblique surface. In theory, the true shape of an oblique surface may be projected onto an oblique plane which is parallel to the oblique surface as shown.


HORIZONTAL PLANE
TOP VIEW
OBLIQUE AUXILIARY PLANE
SECONDARY AUXILIARY VIEW
VERTICAL PLANE
FRONT VIEW
TOP AUXILIARY PLANE
TOP OR PRIMARY AUXILIARY VIEW
(T.V.)
SECONDARY AUXILIARY VIEW
PRIMARY AUXILIARY VIEWS
(F.V.)
AUXILIARY VIEW
ROTATED OR ALIGNED PROJECTION (PREFERRED)
TRUE PROJECTION

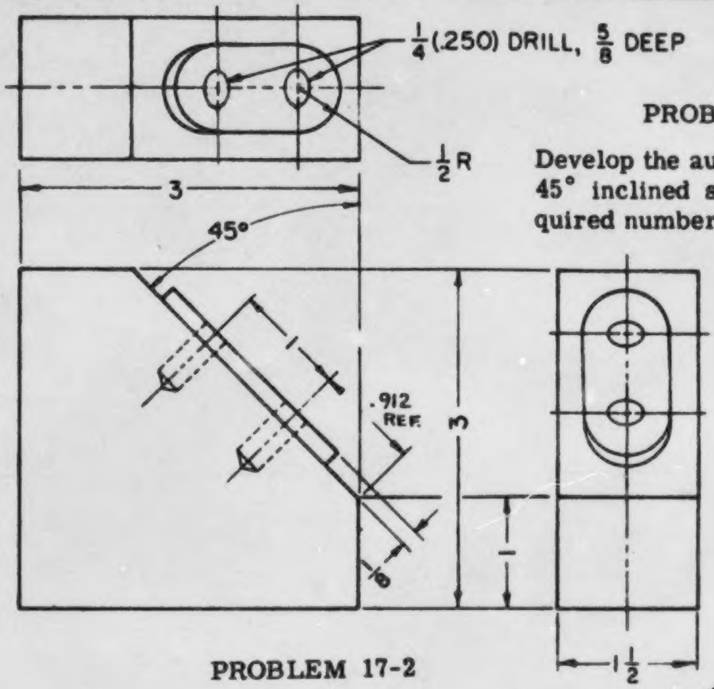
PRIMARY AND SECONDARY AUXILIARY VIEWS

ROTATED OR ALIGNED PROJECTION

Fig. 17–10 Typical Auxiliary Projections

ASSIGNMENT

Prepare drawings (Problems 17-1 through 17-9), following instructions given.

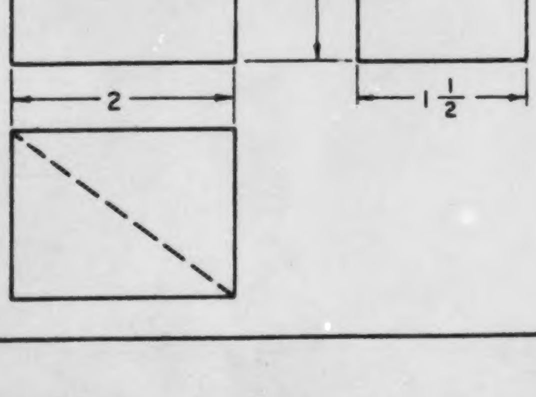

$\frac{1}{4}$(.250) DRILL, $\frac{5}{8}$ DEEP
$\frac{1}{2}$R
3
45°
1
.912 REF.
3
1
$\frac{1}{8}$
$1\frac{1}{2}$

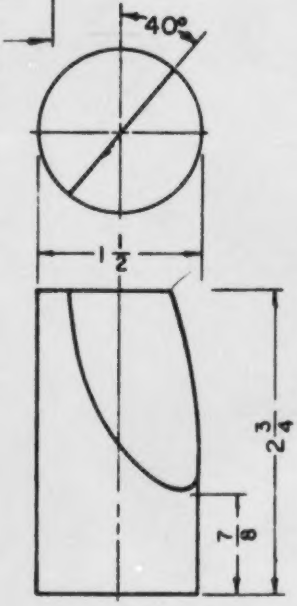
PROBLEM 17-1

Develop the auxiliary view of the 45° inclined surface and the required number of views.

PROBLEM 17-2

Develop the secondary auxiliary view of the inclined surface.


45°
2
3
2
$1\frac{1}{2}$


40°
$1\frac{1}{2}$
$2\frac{3}{4}$
$\frac{7}{8}$

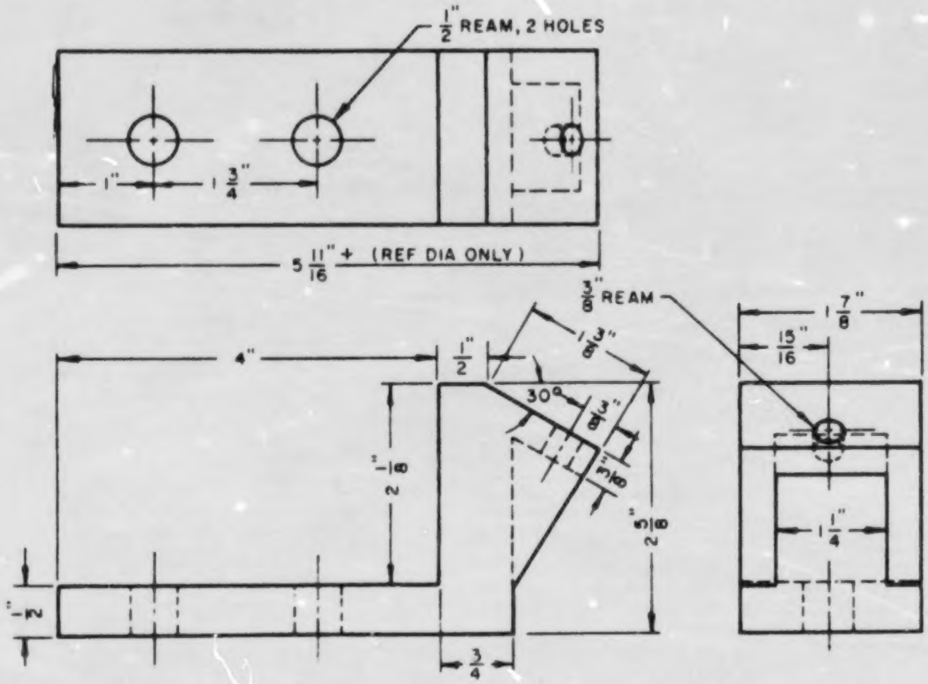
PROBLEM 17-3

Develop the secondary auxiliary view of the inclined surface.

PROBLEM 17-4

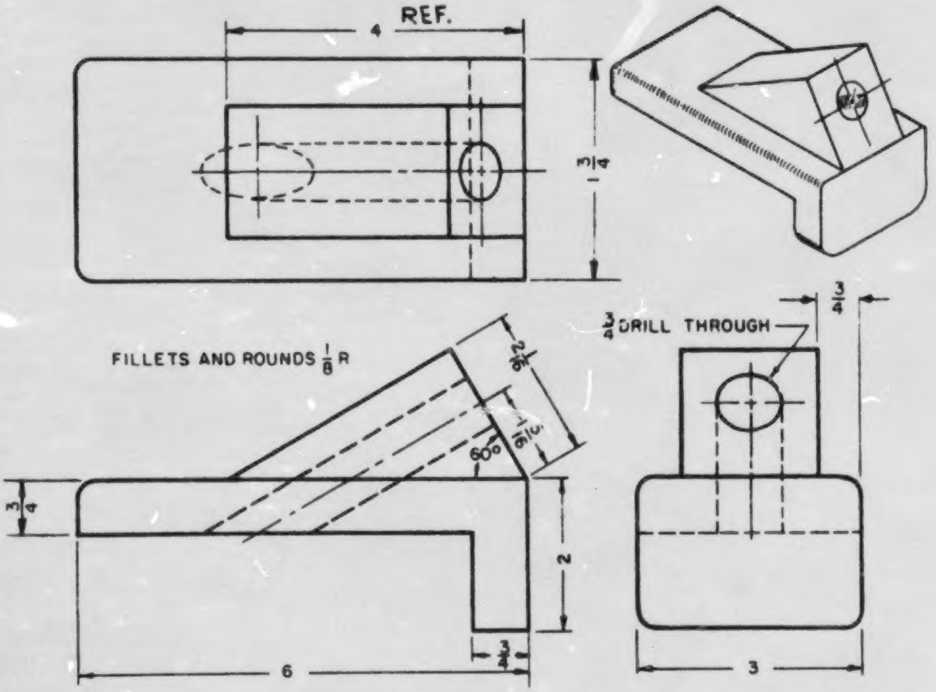
The part shown on this sheet is a bracket used as an instrument board support on an automobile. This object is described by an orthographic drawing of three views.

Make a full size drawing showing the same three views. In addition, make an auxiliary view which is not shown, putting on all necessary dimensions and any other data needed.


1/2" REAM, 2 HOLES
1"
1 3/4"
5 11/16" + (REF DIA ONLY)
3/8" REAM
1 3/8"
4"
1/2"
30°
3/8"
3/8"
2 1/8"
2 5/8"
1/2"
3/4
1 7/8"
15/16"
1 1/4"

PROBLEM 17-5

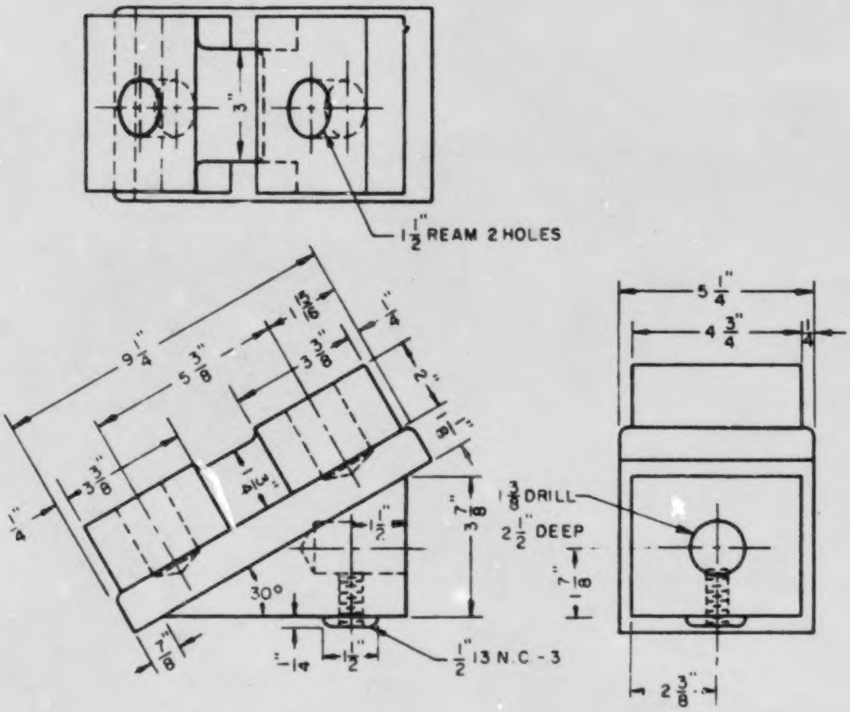
The orthographic drawing below is a shaft support which contains a drilled hole or a rectangular surface. Make a drawing of these three views and add the auxiliary view with the necessary information shown on it. Make this drawing full size.


4 REF.
1 3/4
FILLETS AND ROUNDS 1/8 R
3/4 DRILL THROUGH
3/4
2 1/4
1 5/16
60°
3/4
2
6
3/4
3

PROBLEM 17-6

This heavy bracket is used on large molding machines. The part is described by an orthographic drawing of three views.

Make a drawing showing the same three views. In addition, make an auxiliary view which is not shown, putting on all necessary dimensions and any other data needed. Make this sketch one-quarter size, or 1/4″ = 1″.

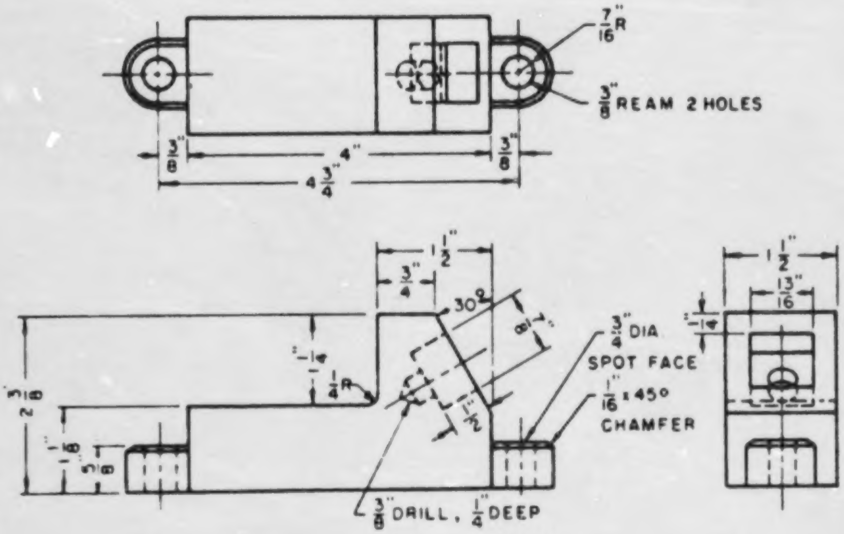

3"
1½" REAM 2 HOLES
9¼"
5⅜"
1 15/16"
¼"
3⅜"
2"
⅜"
3⅜"
¼"
1½"
3⅞"
30°
⅞"
¼"
½"
½" 13 N.C - 3
5¼"
4¾"
¼
1⅜ DRILL
2½" DEEP
1⅞"
2⅜"

FILLETS AND ROUNDS $\frac{1}{16}$ R

PROBLEM 17-7

The orthographic drawing on this page shows a part of a fixture which contains a drilled and a squared hole in one of its surfaces. You will notice that the three views of this piece do not show the size and shape of those holes clearly, nor their location and relation to each other.

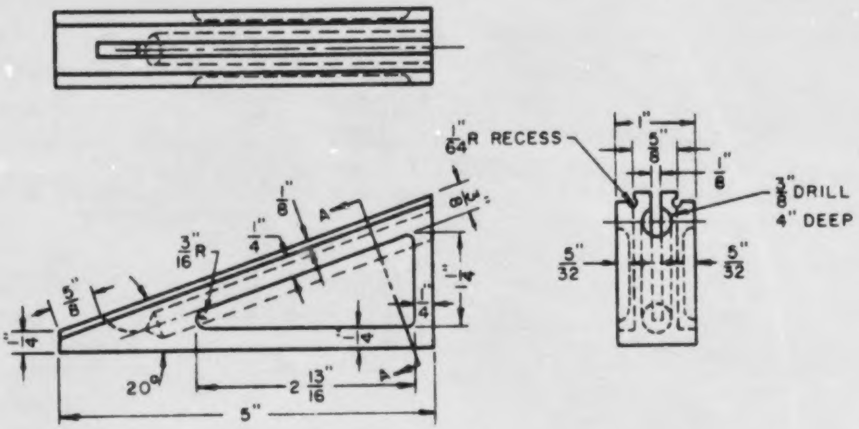
Make a drawing of these three views and add the auxiliary view with the necessary information shown on it. Make this drawing full size.


7/16" R
3/8" REAM 2 HOLES
3/8"
4"
3/8"
4 3/4"
1 1/2"
3/4"
30°
7/8"
1 1/4"
1/4 R
2 3/8"
1 1/8"
5/8"
1/2"
3/4" DIA SPOT FACE
1/16" x 45° CHAMFER
3/8" DRILL, 1/4" DEEP
1 1/2"
13/16"
1/4"

PROBLEM 17-8

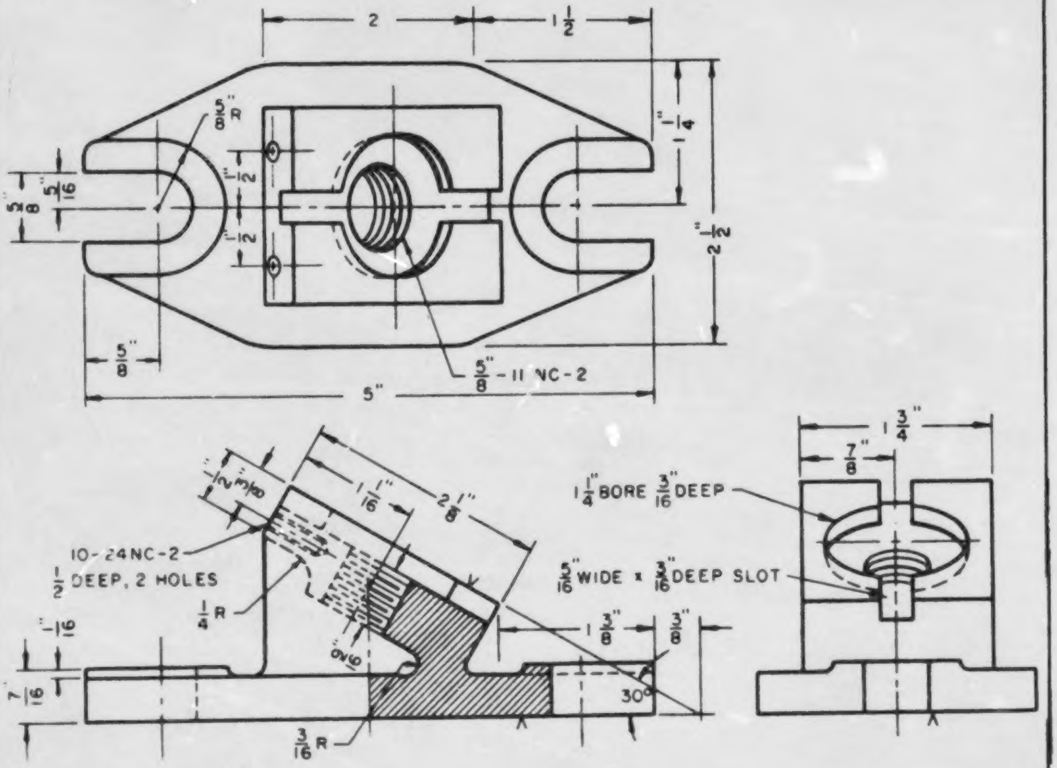
This orthographic drawing shows the base of a sliding parallel. The auxiliary view in this case is used to show the ways or top of the piece on which the other part slides and is developed on reference line A-A.

Make a full size drawing of the three orthographic views, adding the auxiliary view, which should be titled "Section A-A." Place all figures pertaining to the machine work on the top of the auxiliary view.


1/64" R RECESS
1"
5/8"
1/8"
3/8" DRILL
4" DEEP
5/32"
5/32"
1/8"
3/8"
A
1/4"
3/16" R
5/8"
1 1/4"
1/4"
1/4"
1/4"
20°
2 13/16"
A
5"

PROBLEM 17-9

Make a drawing of the three views of the fixture shown below and add any auxiliary views that you think are necessary to complete the information needed for this fixture.

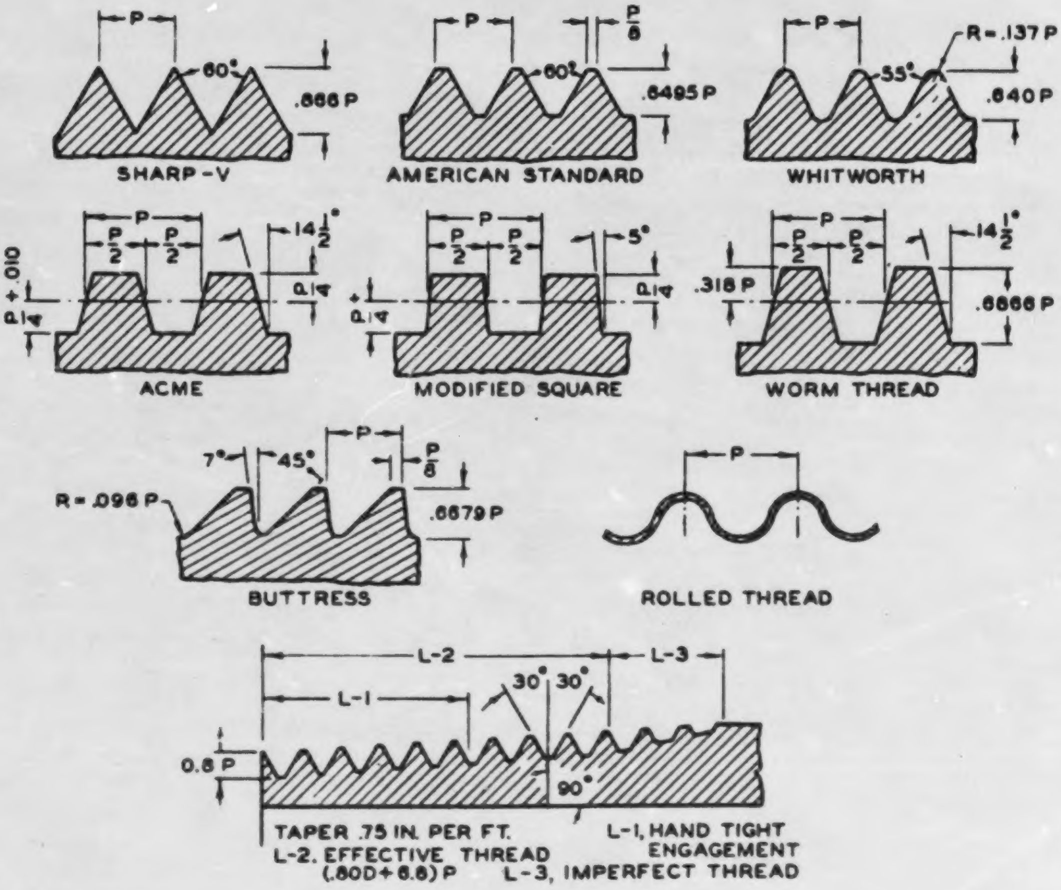

2
1 1/2
5/8" R
1 1/4"
5/16"
5/8"
1/2"
1/2"
2 1/2"
5/8"
5"
5/8"-11 NC-2
1/2"
3/8"
1 1/16"
2 1/8"
10-24NC-2
1/2 DEEP, 2 HOLES
1/4 R
9/16"
1/16"
7/16"
3/16 R
1 3/8"
3/8"
30°
1 3/4"
7/8"
1 1/4" BORE 3/16" DEEP
5/16" WIDE x 3/16" DEEP SLOT

Unit 18 SCREW THREADS

Screw threads have an important part in the construction and operation of machines. Screw threads are used for:

1. fastening parts together
2. making adjustments
3. transmitting power

The purpose of this unit is to describe the several forms of screw threads, their various applications and the conventional methods of representation. The various standard screw-thread forms are described on the following page.


P
60°
.866 P
SHARP-V
P
60°
P/8
.6495 P
AMERICAN STANDARD
P
R=.137 P
55°
.640 P
WHITWORTH
P
P/2
P/2
14 1/2°
+.010
P/4
P/4
ACME
P
P/2
P/2
5°
P/4
P/4
MODIFIED SQUARE
P
P/2
P/2
14 1/2°
.318 P
.6866 P
WORM THREAD
7°
45°
P
P/8
R=.096 P
.6679 P
BUTTRESS
P
ROLLED THREAD
L-2
L-3
L-1
30°
30°
0.8 P
90°
TAPER .75 IN. PER FT.
L-1, HAND TIGHT ENGAGEMENT
L-2. EFFECTIVE THREAD (.80D+6.8) P
L-3, IMPERFECT THREAD

AMERICAN NATIONAL TAPER PIPE THREAD

Fig. 18-1

SCREW-THREAD FORMS

The Sharp-V thread is not commonly used except for some special purposes.

The American National Form of thread, commonly called the American Standard Thread, is most widely used in the United States for fastening parts together.

The Whitworth Standard thread is used principally in Great Britain.

The Acme thread, the 29-Degree Stub thread and the 60-Degree Stub thread (not shown), and the Modified Square thread are used primarily for transmitting power.

The Standard Worm thread is used to transmit power to worm-wheels.

The Buttress thread is designed to take exceptionally high stresses in one direction only, parallel to the thread axis. They are used on the breech-block mechanisms of large guns and airplane propeller hubs.

The American National Rolled threads are used for screw shells of electric sockets and lamp bases.

The American National Taper Pipe threads are used on pipe and pipe fittings. For some applications, the American National Straight Pipe threads (not shown) are used.

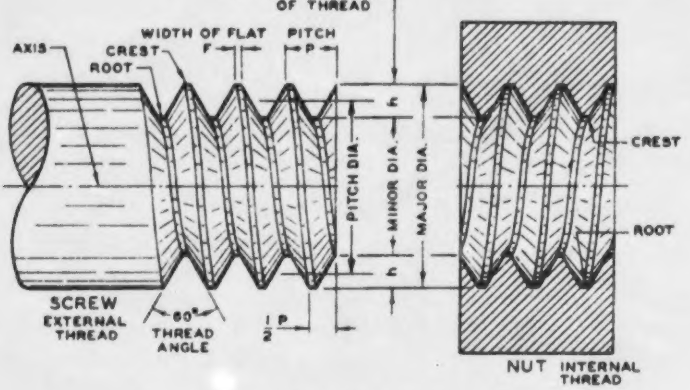

DEPTH OR HEIGHT
OF THREAD
WIDTH OF FLAT
F
PITCH
P
AXIS
CREST
ROOT
h
PITCH DIA.
MINOR DIA.
MAJOR DIA.
h
CREST
ROOT
SCREW
EXTERNAL
THREAD
60°
THREAD
ANGLE
1/2 P
NUT
INTERNAL
THREAD

Fig. 18-2

SCREW-THREAD TERMINOLOGY

The definitions of terms relating to screw-threads are illustrated in Fig. 19-2.

Screw-thread A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder.

External thread A thread on the outside of a member.

Internal thread A thread on the inside of a member. Example: A thread in a nut.

Major Diameter The largest diameter of the thread of a screw or nut.

Minor Diameter The smallest diameter of the thread of a screw or nut.

Pitch The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.

Lead The distance a screw-thread advances axially in one turn. On a single-thread screw, the lead and the pitch are the same; on a double-thread screw the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch.

Angle of Thread The angle included between the sides of the thread measured in an axial plane.

Crest The surface of a thread joining two sides at the major diameter of a screw and the minor diameter of a nut.

Root The surface of a thread joining two sides at the minor diameter of a screw and the major diameter of a nut.

Depth The distance from the root of a thread to a line between two adjacent crests measured perpendicular to the axis.

Axis The center line running lengthwise through a screw.

AMERICAN NATIONAL THREAD SERIES

The American National threads have been classified into six standard thread series as follows: American National coarse, fine, extra-fine, 8-pitch, 12-pitch and 16-pitch thread series.

The American National coarse-thread series (NC) is recommended for general use in machine construction. Sizes range from No. 1 (.073" diameter) to 4" diameter.

The Fine-thread series (NF) is recommended where conditions require a fine thread. Sizes range from No. 0 (.060" diameter) to 1 1/2" diameter.

The Extra-fine series (NEF) is recommended where thin walled material is to be threaded and where depth of thread must be held to a minimum. Sizes range from 1/4" diameter to 2" diameter.

The 8-Pitch thread series (8N) has eight threads per inch for all diameters. It is generally used on bolts for high pressure pipe flanges, cylinder head studs and similar fastenings. Sizes range from 1" diameter to 6" diameter.

The 12-Pitch thread series (12N) has twelve threads per inch for all diameters. It is used in boiler practice and for thin nuts and threaded collars. Sizes range from 1/2" diameter to 6" diameter.

The 16-Pitch thread series (16N) has sixteen threads per inch for all diameters. It is used on threaded adjusting collars. Sizes range from 3/4" diameter to 4" diameter.

CLASSIFICATION OF FITS

Five distinct classes of screw-thread fits have been established as a guide to insure interchangeable manufacture of screw-thread parts throughout the country.

Class 1 Recommended only for screw-thread work where clearance between mating parts is essential for rapid assembly and where shake or play is not objectionable.

Class 2 Represents a high quality of commercial screw-thread product and is recommended for the great bulk of interchangeable screw-thread work.

Class 3 Represents an exceptionally high grade of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking of tools and product is warranted.

Class 4 Intended to meet very unusual requirements more exacting than those for which class 3 is intended. It is a selective fit if initial assembly by hand is required. It is not, as yet, adaptable to quantity production.

Class 5 Includes interchangeable screw-thread work consisting of steel studs set in hard materials (cast iron, steel, bronze, etc.) where a wrench-tight fit is required.

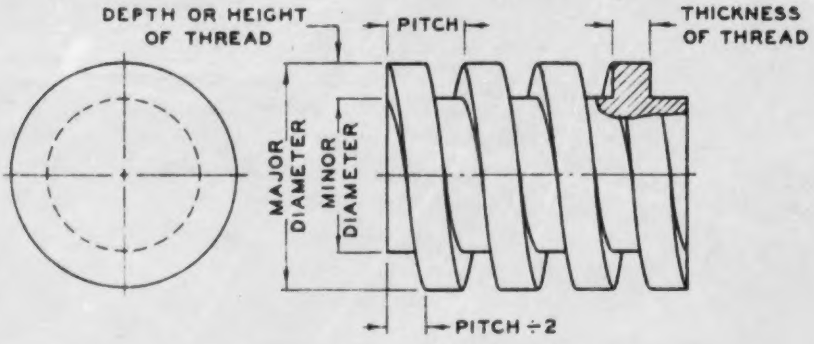


Fig. 18-3

SQUARE SCREW-THREADS

Square threads are used for another purpose. Square threads transmit motion or power in a direction parallel to the axis of the screw. For example: square threads are used on some vise screws. As the screw is turned, it causes the vise jaw to move (transmits motion) in a direction parallel to the axis of the screw. Also, power or force applied to the handle attached to the screw is transmitted through the screw to the vise jaw. It is this force that clamps the work in the vise. Square threads are used on lifting jacks, on elevating screws, on the screws in hand clamps and other similar applications.

SEMI-CONVENTIONAL SQUARE THREADS

Square threads, like other screw-threads are in the form of a helix (Fig. 18-3). To conserve drafting time, the curved lines of the helix are drawn with straight lines as shown in the semi-conventional square screw-thread representation, Fig. 18-4.

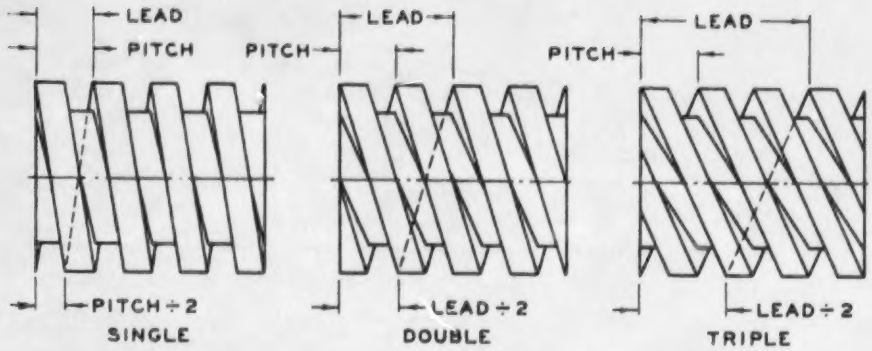


Fig. 18-4

The Single Lead thread is a thread having one continuous thread ridge forming a helix. The pitch and lead are equal.

The Double Lead thread is a thread having two continuous thread ridges side-by-side forming a helix. The lead is twice the pitch.

The Triple Lead thread is a thread having three continuous thread ridges side-by-side forming a helix. The lead is three times the pitch.

TERMINOLOGY

The pitch of a square thread is the distance from a point on a thread to the corresponding point on the next thread measured parallel to the axis. To find the pitch, divide one inch by the number of threads per inch.

The lead is the distance a screw-thread advances axially in one turn. On a single-thread screw, the lead and the pitch are the same; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch.

The depth of a square thread is one-half of the pitch.

The thickness of a square thread is one-half of the pitch.

ACME THREADS

Acme threads are specified on drawings by giving the major diameter of the threads, the type of thread and the number of threads per inch. Example: 1 3/4" Acme, 4 thds. per in. A multiple Acme thread is indicated by adding "double," "triple" or "quadruple" to the thread notation. Left-hand threads are indicated as LH.

The A.S.A. has standardized the Acme and Stub Acme threads into three classes: 2G, 3G and 4G for general purpose use and five classes: 2C, 3C, 4C, 5C and 6C for centralizing Acme threads for close fits.

Specifications for Acme threads:

1 3/4 - 4 Acme - 2G
Dia. Thds. Class

2 7/8 - 0.4P - 0.8L Acme - 3G
Dia. Pitch Lead Class

3/4 - 6 Stub Acme
Dia. Thds.

1 - 5 Acme - 4C LH
Dia. Thds. Class Left hand

SYMBOLS FOR IDENTIFYING AMERICAN STANDARD THREADS

American standard threads are specified by stating (1) the diameter, (2) the number of threads per inch, (3) the thread series, NC, NF, NEF, 8N, 12N, 16N and (4) the class of fit. For a left-hand thread, the letters LH are placed after the class of fit. Thread identification symbols are shown below.

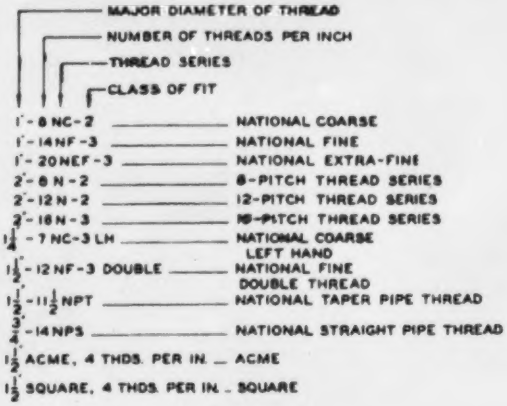

MAJOR DIAMETER OF THREAD
NUMBER OF THREADS PER INCH
THREAD SERIES
CLASS OF FIT
1" - 8 NC - 2 — NATIONAL COARSE
1" - 14 NF - 3 — NATIONAL FINE
1" - 20 NEF - 3 — NATIONAL EXTRA-FINE
2" - 8 N - 2 — 8-PITCH THREAD SERIES
2" - 12 N - 2 — 12-PITCH THREAD SERIES
2" - 16 N - 3 — 16-PITCH THREAD SERIES
1¼" - 7 NC - 3 LH — NATIONAL COARSE LEFT HAND
1½" - 12 NF - 3 DOUBLE — NATIONAL FINE DOUBLE THREAD
1½" - 11½ NPT — NATIONAL TAPER PIPE THREAD
¾" - 14 NPS — NATIONAL STRAIGHT PIPE THREAD
1½" ACME, 4 THDS. PER IN. — ACME
1½" SQUARE, 4 THDS. PER IN. — SQUARE

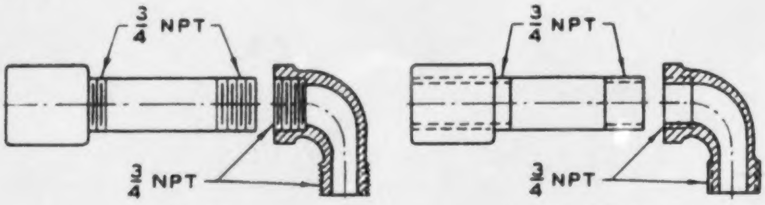
Fig. 18-5

AMERICAN NATIONAL PIPE THREADS

Screw-threads are used on pipe and pipe fittings. The angle between the sides of American National Pipe Threads is 60 degrees. The crests and the roots are flattened or truncated a minimum of 0.033 times the pitch. The depth of the threads is 0.80 times the pitch.

For tight fitting joints, the American National Taper Pipe Threads are used. These threads have a taper of 3/4" per foot, or 1/16" per inch and were illustrated before in Fig. 18-1. For other purposes, the American National Straight Pipe Threads are used.

The regular and simplified pipe thread symbols for external and internal threads are shown below.


3/4 NPT
3/4 NPT
3/4 NPT
3/4 NPT

REGULAR SIMPLIFIED

Fig. 18-6

SPECIFYING PIPE THREADS

Pipe threads are specified on drawings by stating the nominal size of the pipe. This is followed by the letters NPT for tapered pipe threads, or the letters NPS for straight pipe threads. Examples: 3/4" - NPT; 1" - NPS

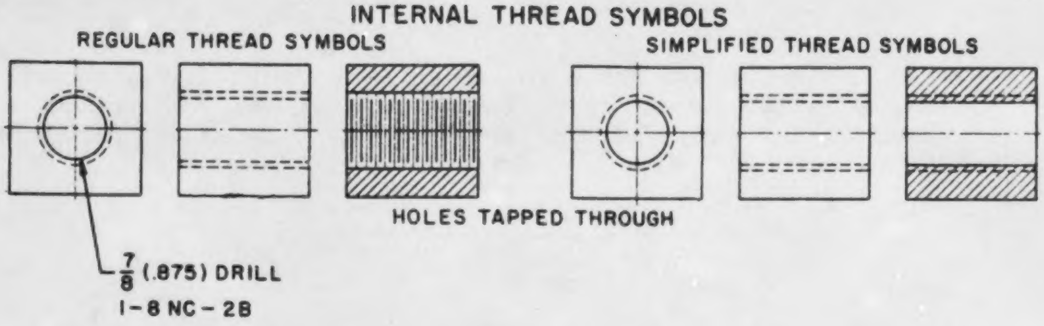

INTERNAL THREAD SYMBOLS
REGULAR THREAD SYMBOLS
SIMPLIFIED THREAD SYMBOLS
HOLES TAPPED THROUGH
$\frac{7}{8}$ (.875) DRILL
1-8 NC-2B

Fig. 18-7

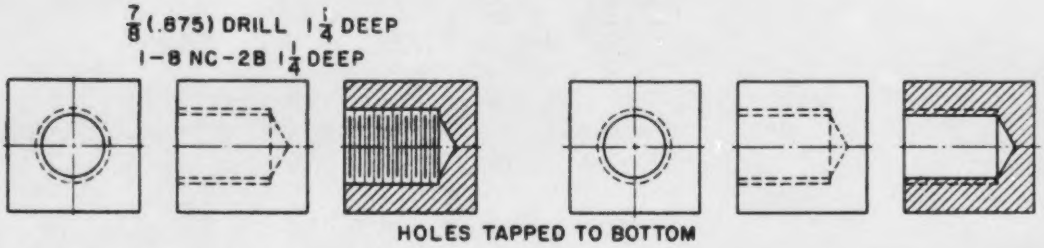

$\frac{7}{8}$ (.875) DRILL $1\frac{1}{4}$ DEEP
1-8 NC-2B $1\frac{1}{4}$ DEEP
HOLES TAPPED TO BOTTOM

Fig. 18-8

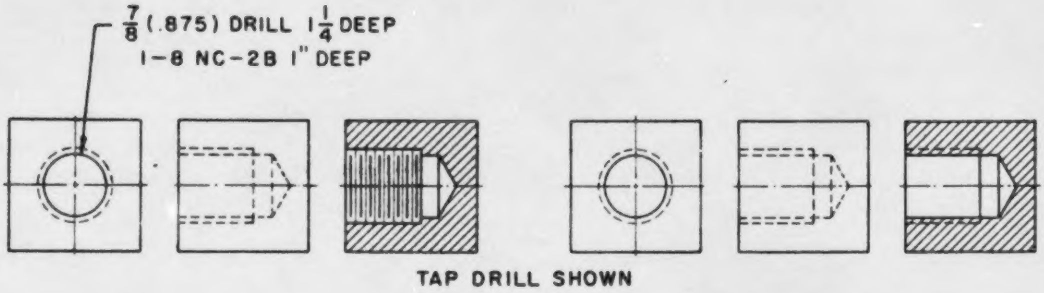

$\frac{7}{8}$ (.875) DRILL $1\frac{1}{4}$ DEEP
1-8 NC-2B 1" DEEP
TAP DRILL SHOWN

Fig. 18-9

REGULAR AND SIMPLIFIED INTERNAL THREAD SYMBOLS

The regular and simplified symbols are the same except for the sectional view. The long and short line in the regular sectional view are eliminated and hidden and solid lines are shown, see Figs. 18-8, 18-9 and 18-10.

The thread symbols for assembly drawings as shown in Figs. 18-11 and 18-12 are for the regular or simplified symbols. When both external and internal threads are engaged, the V-threads must be shown for classification. All standard items such as nuts, bolts, studs, screws and shafting need not be sectioned unless internal clarification of the part is necessary.

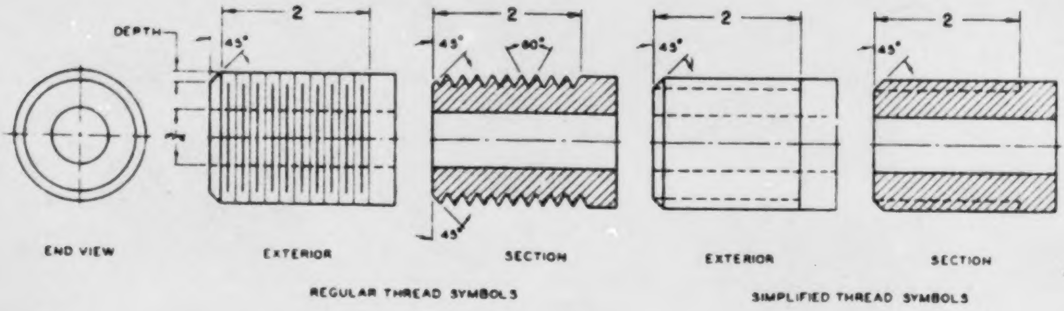
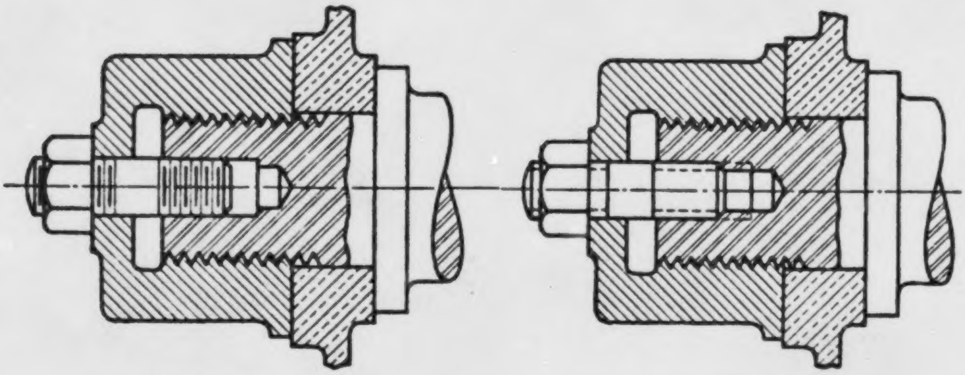

DEPTH
2
45°
60°
END VIEW
EXTERIOR
SECTION
EXTERIOR
SECTION
REGULAR THREAD SYMBOLS
SIMPLIFIED THREAD SYMBOLS

Fig. 18-10



REGULAR

SIMPLIFIED

Fig. 18-11

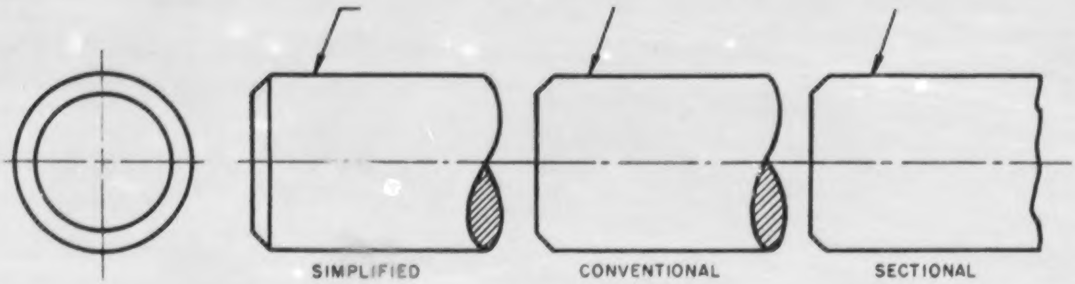
ASSIGNMENT

1. Draw a 2 1/2 - 4 single lead semi-conventional external thread, 3" long. Locate the Crest, Root, Thread Angle, Pitch Lead, Pitch Diameter, Major Diameter, Minor Diameter.

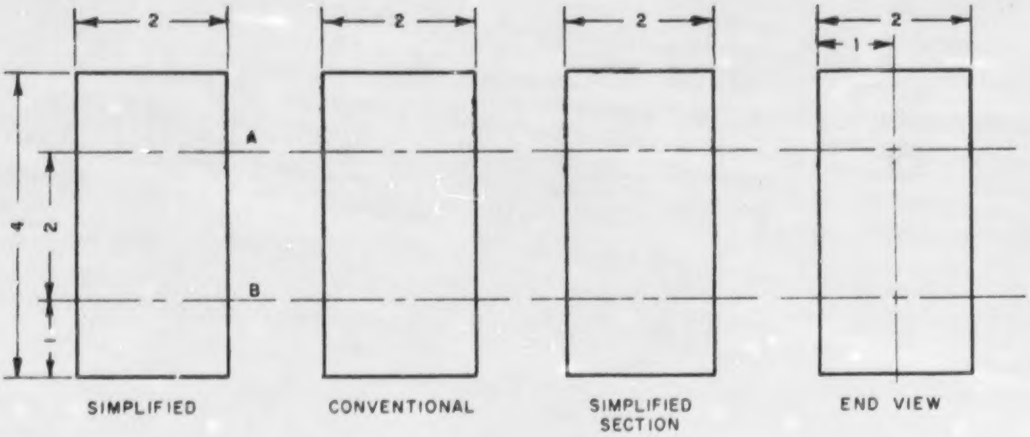
2. Draw a 1 1/2 - 4 Acme - 2G double lead semi-conventional external thread, 3" long. Locate the Crest, Root, Thread Angle, Pitch Diameter, Pitch Lead, Major Diameter, Minor Diameter.

3. Draw a 2 1/2 - 4 square double lead semi-conventional external thread, 3" long. Locate the Crest, Root, Pitch, Lead, Pitch Diameter, Major Diameter, Minor Diameter.

4. Draw the three types of threads as noted (7/8 - 9NC - 2, length of thread 1 1/2). Give thread notes and chamfer.


SIMPLIFIED
CONVENTIONAL
SECTIONAL

5. Draw the thread symbols noted (7/8 - 9NC - 2, "A" is a thru thread, "B" is a depth thread, 1 3/8 deep). Give the correct thread notations in the end view.


2
2
2
2
1
A
B
4
2
1
SIMPLIFIED
CONVENTIONAL
SIMPLIFIED SECTION
END VIEW

Unit 19 DETAIL ASSEMBLY

DESIGN DRAWINGS

Design drawings or design layouts constitute the ideas and sketches submitted by the engineering manager and his staff. The drawings contain details, sectional view and auxiliary view to clarify certain areas. The drawings show clearances of moving parts, assembly methods, serviceability, production and interchangeability of parts, etc. The draftsman makes assembly drawings from the design drawings.

ASSEMBLY DRAWINGS

The assembly drawing is an orthographic projection which consists of details, standard parts, sections, auxiliary views (if necessary), a bill of material, general notes, and title block.

Subassembly

The subassembly consists of details and standard parts which must be assembled as a unit before it can be joined to the main assembly. In some industries, the subassembly is used as the procedure for fabrication.

Outline Assembly

The outline assembly, or the installation drawing, consists of the overall dimensions and other information for mounting, connecting to a system and operation.

Details

The detail drawing is a single part in an orthographic projection, giving dimensions, the scale of the drawing, material specification, finish notes, the bill of material, number of parts required, etc.

Standard Parts

Standard parts are those items purchased, such as bolts, nuts, screws, bearings, gears, washers, bushings, taper pins, keys, etc. These parts are not detailed unless the part is modified.

Bill of Material

The bill of material is located in the upper right-hand corner of the detail, or assembly, listing the part number, name, number required, type of material, material specifications, material size, etc.

Drawing Sizes

The following is a listing of A.S.A. drawing sizes used in the drafting and engineering departments.

Letter	Size	Letter	Size
A	8 1/2 × 11	D	22 × 34
B	11 × 17	E	34 × 44
C	17 × 22		

Title Block

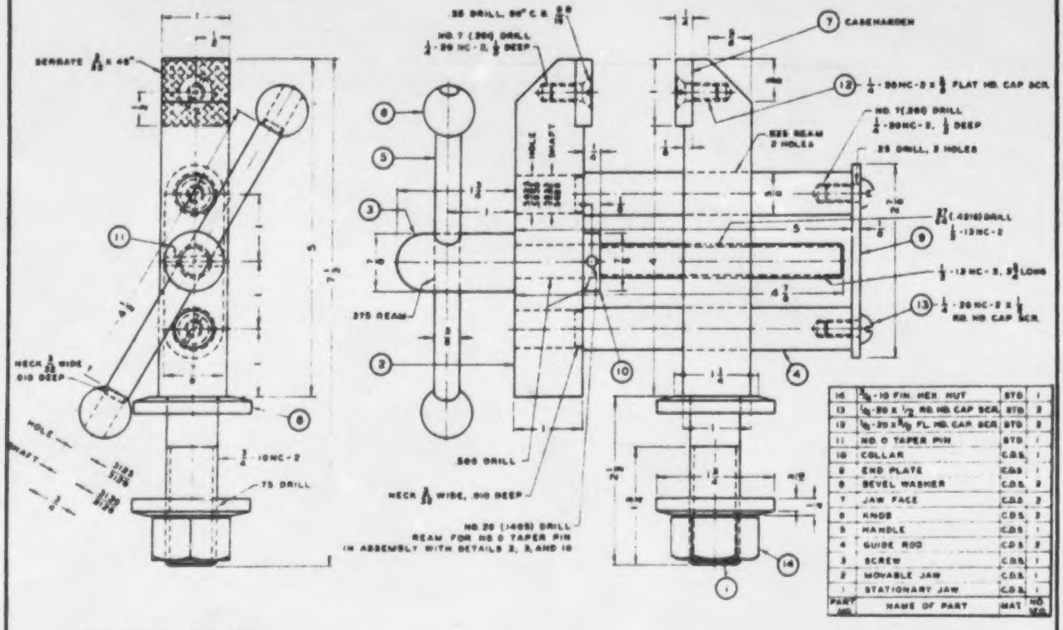
The title block is located in the lower right-hand corner of the detail or assembly drawing. It consists of the part number, name of part, drawn by, traced by, checked by, engineering approval, model number and the name of company.

Revision Block

The revision block is located in the lower right-hand corner to the left or above the title block. Its function is to note, by a letter, corrections of the detail.

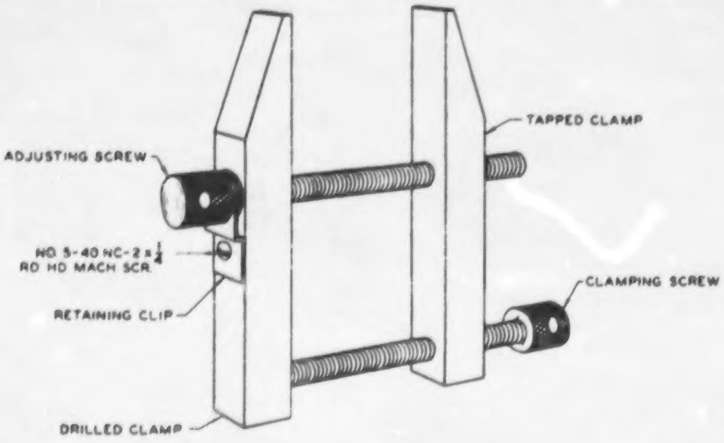
ASSIGNMENT

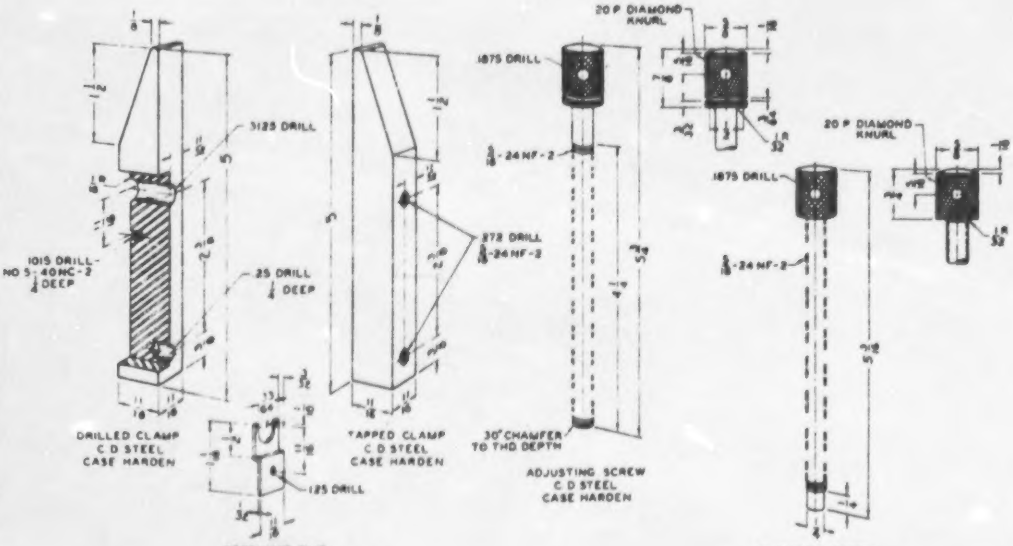
Problems 19-1 through 19-5: Detail each part on a separate sheet. Include a bill of material and title block.


SERRATE
⑦ CASEHARDEN
⑫ 1/4-20NC-2 x 5/8 FLAT HD. CAP SCR.
NO. 7 (.201) DRILL 1/4-20NC-2, 1/2 DEEP
.25 DRILL, 2 HOLES
(.4219) DRILL 1/2-13NC-2
1/2-13NC-2, 5 3/4 LONG
⑬ 1/4-20NC-2 x 1/2 RD. HD. CAP SCR.
.375 REAM
.500 DRILL
NECK 1/16 WIDE, .010 DEEP
NO. 20 (.1405) DRILL
REAM FOR NO. 0 TAPER PIN
IN ASSEMBLY WITH DETAILS 2, 3, AND 10
HOLE
SHAFT
.75 DRILL
1/2-10NC-2
①
③
④
⑤
⑥
⑧
⑨
⑩
⑪
⑭

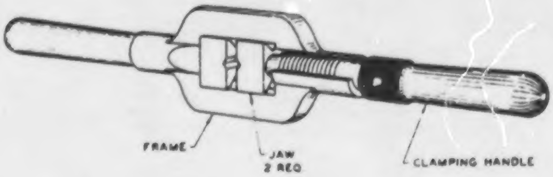
PART NO.	NAME OF PART	MAT	NO. REQ.
14	5/8-10 FIN. HEX. NUT	STD	1
13	1/4-20 x 1/2 RD. HD. CAP SCR.	STD	2
12	1/4-20 x 5/8 FL. HD. CAP SCR.	STD	2
11	NO. 0 TAPER PIN	STD	1
10	COLLAR	C.R.S.	1
9	END PLATE	C.R.S.	1
8	BEVEL WASHER	C.R.S.	2
7	JAW FACE	C.R.S.	2
6	KNOB	C.R.S.	2
5	HANDLE	C.R.S.	1
4	GUIDE ROD	C.R.S.	2
3	SCREW	C.R.S.	1
2	MOVABLE JAW	C.R.S.	1
1	STATIONARY JAW	C.R.S.	1

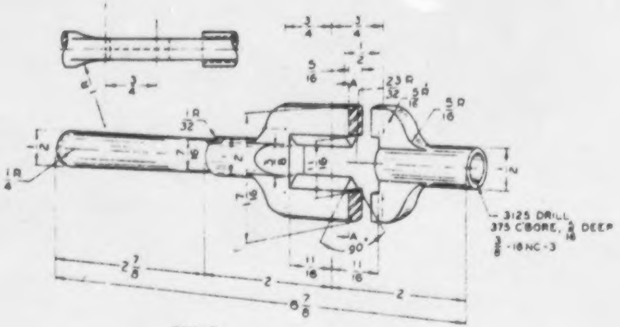
PROBLEM 19-1


TAPPED CLAMP
ADJUSTING SCREW
NO 5-40 NC-2 x 1/4 RD HD MACH SCR
CLAMPING SCREW
RETAINING CLIP
DRILLED CLAMP

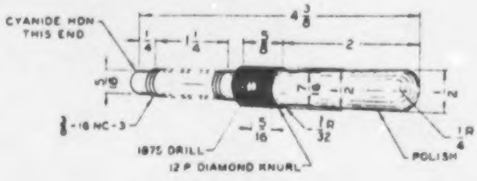

.3125 DRILL
1015 DRILL-
NO 5-40NC-2
1/4 DEEP
.25 DRILL
1/4 DEEP
DRILLED CLAMP
C D STEEL
CASE HARDEN
.125 DRILL
RETAINING CLIP
SPRING STEEL
HARDEN AND TEMPER
.272 DRILL
5/16-24NF-2
TAPPED CLAMP
C D STEEL
CASE HARDEN
.1875 DRILL
5/16-24NF-2
30° CHAMFER
TO THD DEPTH
ADJUSTING SCREW
C D STEEL
CASE HARDEN
20 P DIAMOND KNURL
1/32 R
.1875 DRILL
5/16-24NF-2
20 P DIAMOND KNURL
1/32 R
CLAMPING SCREW
C D STEEL-CASE HARDEN

PROBLEM 19 2

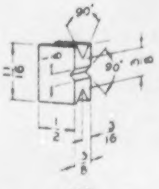

FRAME
JAW
2 REQ
CLAMPING HANDLE


3/4
3/4
1/2
5/16
A
23/32 R
5/16 R
5/16 R
1/32 R
3/4
1/2
1/4 R
7/16
1/2
5/16
1/16
3/16
.3125 DRILL
.375 C'BORE, 3/16 DEEP
3/8 - 16 NC - 3
A
90°
11/16
11/16
2 7/8
2
2
6 7/8

FRAME
C D STEEL
POLISH OUTSIDE

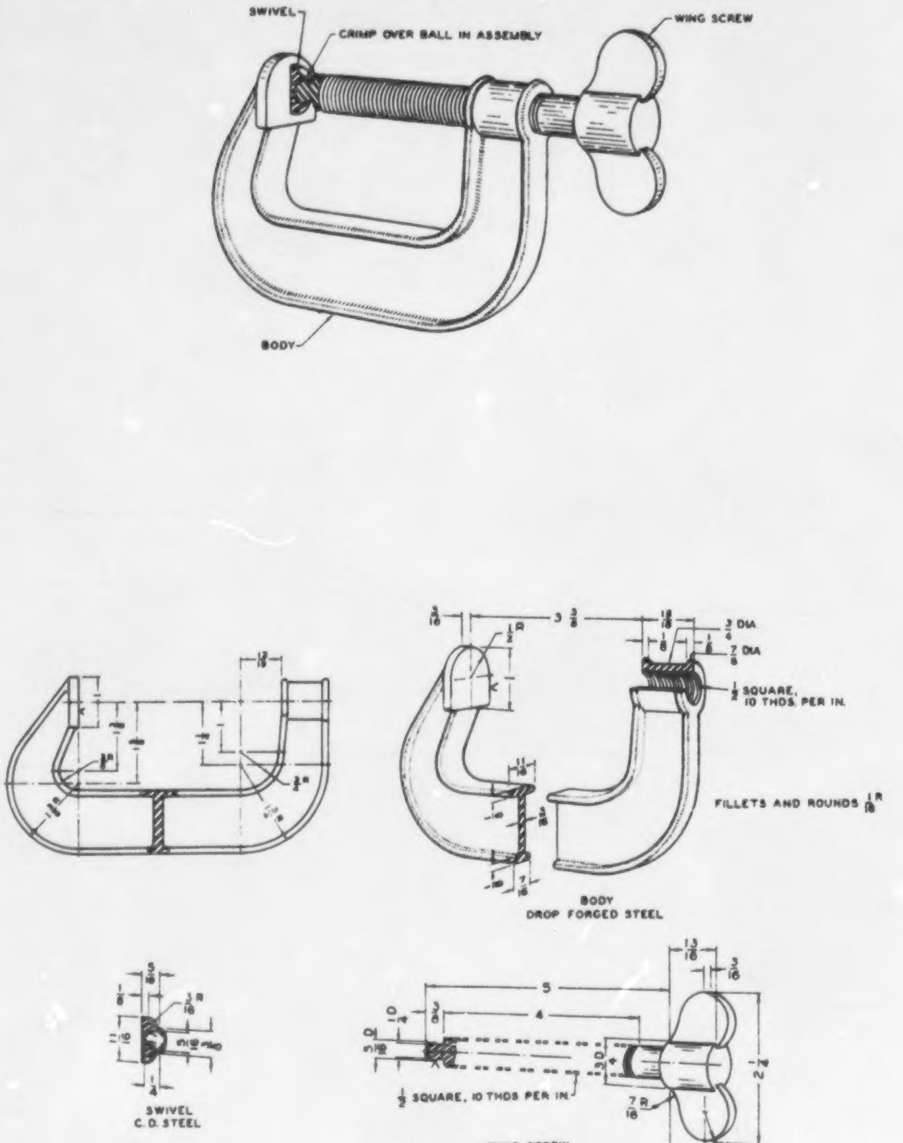

CYANIDE HDN
THIS END
4 3/8
1/4
1 1/4
5/8
2
5/16
7/16
1/2
1/2
3/8 - 16 NC - 3
5/16
1/32 R
1/4 R
.1875 DRILL
12 P DIAMOND KNURL
POLISH

CLAMPING HANDLE
C D STEEL

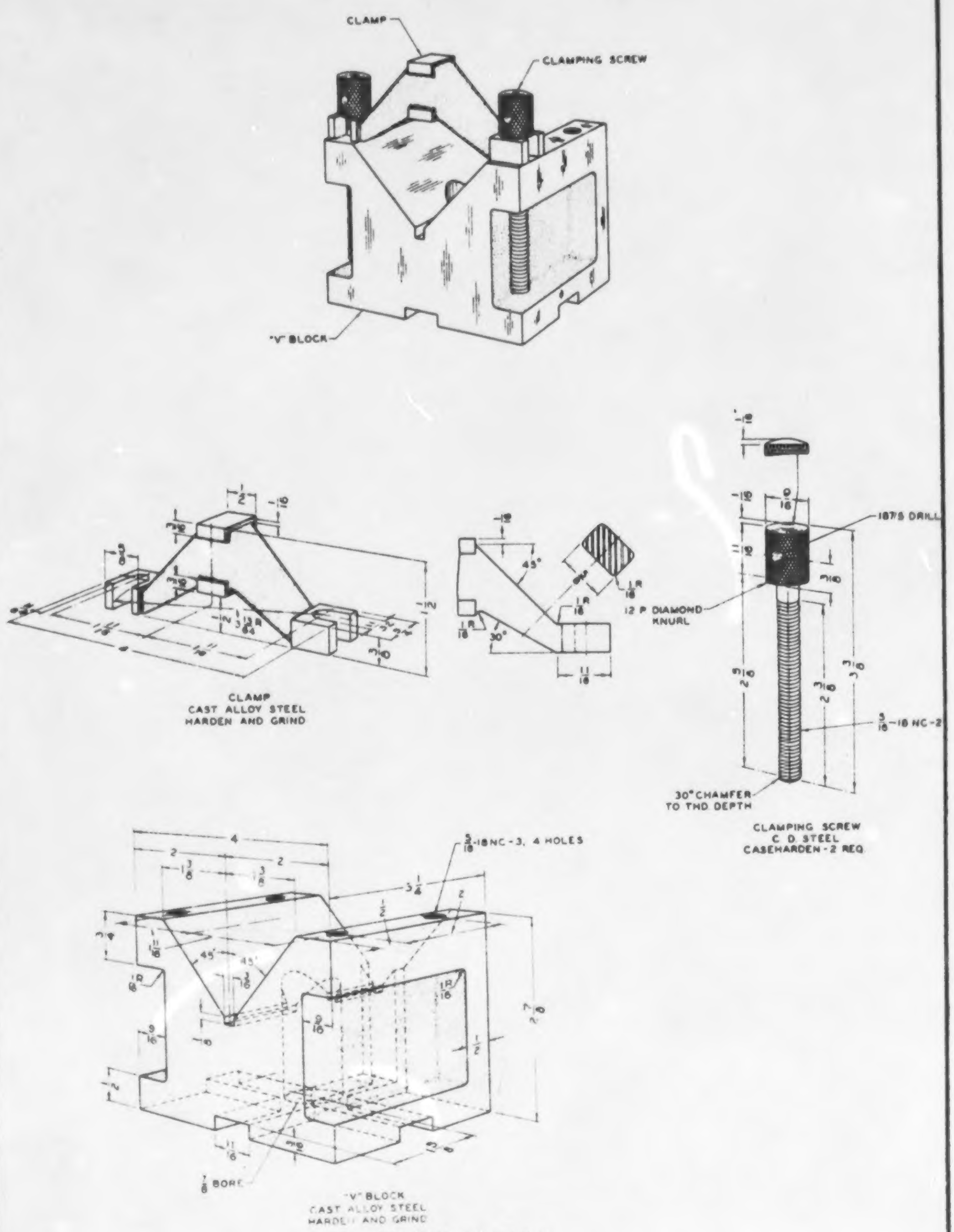

90°
11/16
1/16
90°
5/16
1/2
3/16
3/8

JAW
TOOL STEEL - HARDEN
2 REQ

PROBLEM 19-3


SWIVEL
CRIMP OVER BALL IN ASSEMBLY
WING SCREW
BODY
3 3/8
3/4 DIA
7/8 DIA
1/2 SQUARE, 10 THDS. PER IN.
FILLETS AND ROUNDS 1/16 R
BODY
DROP FORGED STEEL
SWIVEL
C. D. STEEL
5
4
1/2 SQUARE, 10 THDS PER IN.
2 1/4
7/16 R
WING SCREW
DROP FORGED STEEL

PROBLEM 19-4


CLAMP
CLAMPING SCREW
"V" BLOCK
CLAMP
CAST ALLOY STEEL
HARDEN AND GRIND
45°
30°
12 P DIAMOND KNURL
.1875 DRILL
$\frac{5}{16}$-18 NC-2
30° CHAMFER TO THD DEPTH
CLAMPING SCREW
C. D. STEEL
CASEHARDEN - 2 REQ.
4
2
2
$1\frac{3}{8}$
$\frac{3}{8}$
$\frac{5}{16}$-18NC-3, 4 HOLES
$3\frac{1}{4}$
2
$\frac{7}{8}$ BORE
"V" BLOCK
CAST ALLOY STEEL
HARDEN AND GRIND

PROBLEM 19-5

APPENDIX

TABLES

I Decimal Equivalents 172
II Screw Thread Diameters and Numbers of Threads per Inch 173
III Tap Drill Sizes for American Standard Threads . . 174
IV American Standard Wrench Head Bolts and Nuts — Regular Series 176
V American Standard Wrench Head Bolts and Nuts — Heavy Series 177
VI Recommended Minimum Thread Lengths for Bolts . 178
VII Dimensions of Cap Screw Heads 179
VIII Dimensions of Machine Screw Heads . . . 180
IX Dimensions of Machine Screw and Stove Bolt Nuts 182
X Dimensions of Square Head and Headless Set Screws 183
XI Dimensions of American National Taper Pipe Threads 184
XII Standard Tables of English Measure 185
XIII Standard Tables of Metric Measure 186

Table I

DECIMAL EQUIVALENTS

DECIMAL EQUIVALENTS

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1	1.

Table II

SCREW THREAD DIAMETERS AND NUMBER OF THREADS PER INCH

Diameter	National Coarse N.C.	National Fine N.F.	National Extra-Fine N.E.F.	8-Pitch 8N	12-Pitch 12N	16-Pitch 16N	Acme
No. 0 -.060	—	80	—	—	—	—	—
1 -.073	64	72	—	—	—	—	—
2 -.086	56	64	—	—	—	—	—
3 -.099	48	56	—	—	—	—	—
4 -.112	40	48	—	—	—	—	—
5 -.125	40	44	—	—	—	—	—
6 -.138	32	40	—	—	—	—	—
8 -.164	32	36	—	—	—	—	—
10 -.190	24	32	—	—	—	—	—
12 -.216	24	28	—	—	—	—	—
1/4	20	28	32	—	—	—	16
5/16	18	24	32	—	—	—	14
3/8	16	24	32	—	—	—	12
7/16	14	20	28	—	—	—	12
1/2	13	20	28	—	12	—	10
9/16	12	18	24	—	12	—	—
5/8	11	18	24	—	12	—	8
11/16	—	—	24	—	12	—	—
3/4	10	16	20	—	12	16	6
13/16	—	—	20	—	12	16	—
7/8	9	14	20	—	12	16	6
15/16	—	—	20	—	12	16	—
1	8	14	20	8	12	16	5
1 1/16	—	—	18	—	12	16	—
1 1/8	7	12	18	8	12	16	5
1 3/16	—	—	18	—	12	16	—
1 1/4	7	12	18	8	12	16	5
1 5/16	—	—	18	—	12	16	—
1 3/8	6	12	18	8	12	16	4
1 7/16	—	—	18	—	12	16	—
1 1/2	6	12	18	8	12	16	4
1 9/16	—	—	18	—	—	16	—
1 5/8	—	—	18	8	12	16	—
1 11/16	—	—	18	—	—	16	—
1 3/4	5	—	16	8	12	16	4
1 13/16	—	—	—	—	—	16	—
1 7/8	—	—	—	8	12	16	—
1 15/16	—	—	—	—	—	16	—
2	4 1/2	—	16	8	12	16	4
2 1/16	—	—	—	—	—	16	—
2 1/8	—	—	—	8	12	16	—
2 3/16	—	—	—	—	—	16	—
2 1/4	4 1/2	—	—	8	12	16	3
2 5/16	—	—	—	—	—	16	—
2 3/8	—	—	—	—	12	16	—
2 7/16	—	—	—	—	—	16	—
2 1/2	4	—	—	8	12	16	3
2 5/8	—	—	—	—	12	16	—
2 3/4	4	—	—	8	12	16	3
2 7/8	—	—	—	—	12	16	—
3	4	—	—	8	12	16	2
3 1/8	—	—	—	—	12	16	—
3 1/4	4	—	—	8	12	16	—
3 3/8	—	—	—	—	12	16	—
3 1/2	4	—	—	8	12	16	2
3 5/8	—	—	—	—	12	16	—
3 3/4	4	—	—	8	12	16	—
3 7/8	—	—	—	—	12	16	—
4	4	—	—	8	12	16	2
4 1/4	—	—	—	8	12	—	—
4 1/2	—	—	—	8	12	—	2
4 3/4	—	—	—	8	12	—	—
5	—	—	—	8	12	—	2
5 1/4	—	—	—	8	12	—	—
5 1/2	—	—	—	8	12	—	—
5 3/4	—	—	—	8	12	—	—
6	—	—	—	8	12	—	—

Table III

TAP DRILL SIZES FOR AMERICAN STANDARD THREADS

Diam. of Thread	Threads per Inch	Drill*	Decimal Equiv.
No. 0-.060	80 NF	3/64	.0469
1-.073	64 NC	1.5 MM	.0591
	72 NF	53	.0595
2-.086	56 NC	50	.0700
	64 NF	50	.0700
3-.099	48 NC	5/64	.0781
	56 NF	45	.0820
4-.112	40 NC	43	.0890
	48 NF	42	.0935
5-.125	40 NC	38	.1015
	44 NF	37	.1040
6-.138	32 NC	36	.1065
	40 NF	33	.1130
8-.164	32 NC	29	.1360
	36 NF	29	.1360
10-.190	24 NC	25	.1495
	32 NF	21	.1590
12-.216	24 NC	16	.1770
	28 NF	14	.1820
1/4	20 NC	7	.2010
	28 NF	3	.2130
	32 NEF	7/32	.2188
5/16	18 NC	F	.2570
	24 NF	I	.2720
	32 NEF	9/32	.2812
3/8	16 NC	5/16	.3125
	24 NF	Q	.3320
	32 NEF	11/32	.3438
7/16	14 NC	U	.3680
	20 NF	25/64	.3906
	28 NEF	Y	.4040
1/2	12 N	27/64	.4219
	13 NC	27/64	.4219
	20 NF	29/64	.4531
	28 NEF	15/32	.4687
9/16	12 NC	31/64	.4844
	18 NF	33/64	.5156
	24 NEF	33/64	.5156
5/8	11 NC	17/32	.5312
	12 N	35/64	.5469
	18 NF	14.5 MM	.5709
	24 NEF	37/64	.5781
11/16	12 N	39/64	.6094
	24 NEF	16.5 MM	.6496
3/4	10 NC	16.5 MM	.6496
	12 N	17 MM	.6693
	16 NF	17.5 MM	.6890
	20 NEF	45/64	.7031
13/16	12 N	18.5 MM	.7283
	16 N	3/4	.7500
	20 NEF	49/64	.7656
7/8	9 NC	49/64	.7656
	12 N	20 MM	.7874
	14 NF	20.5 MM	.8071
	16 N	13/16	.8125
	20 NEF	21 MM	.8268
15/16	12 N	55/64	.8594
	16 N	7/8	.8750
	20 NEF	22.5 MM	.8858
1	8 NC	7/8	.8750
	12 N	59/64	.9219
	14 NF	23.5 MM	.9252
	16 N	15/16	.9375
	20 NEF	61/64	.9531
1 1/16	12 N	25 MM	.9843
	16 N	1	1.0000
	18 NEF	25.5 MM	1.0040
1 1/8	7 NC	63/64	.9844
	8 N	25.5 MM	1.0039
	12 NF	26.5 MM	1.0433
	16 N	1 1/16	1.0625
	18 NEF	1 5/64	1.0781
1 3/16	12 N	28 MM	1.1024
	16 N	1 1/8	1.1250
	18 NEF	1 9/64	1.1406
1 1/4	7 NC	1 7/64	1.1094
	8 N	1 1/8	1.1250
	12 NF	29.5 MM	1.1614
	16 N	1 3/16	1.1875
	18 NEF	30.5 MM	1.2008
1 5/16	12 N	1 15/64	1.2344
	16 N	1 1/4	1.2500
	18 NEF	32 MM	1.2598

*To produce approximately 75% full thread

Table III

TAP DRILL SIZES FOR AMERICAN STANDARD THREADS

Diam. of Thread	Threads per Inch	Drill*	Decimal Equiv.
1 3/8	6 NC	1 13/64	1.2031
	8 N	1 1/4	1.2500
	12 NF	1 19/64	1.2969
	16 N	1 5/16	1.3125
	18 NEF	33.5 MM	1.3189
1 7/16	12 N	34.5 MM	1.3583
	16 N	1 3/8	1.3750
	18 NEF	35 MM	1.3780
1 1/2	6 NC	1 21/64	1.3281
	8 N	1 3/8	1.3750
	12 NF	36 MM	1.4173
	16 N	1 7/16	1.4375
	18 NEF	1 29/64	1.4531
1 9/16	16 N	1 1/2	1.5000
	18 NEF	1 33/64	1.5156
1 5/8	8 N	1 1/2	1.5000
	12 N	39 MM	1.5354
	16 N	1 9/16	1.5625
	18 NEF	40 MM	1.5748
1 11/16	16 N	1 5/8	1.6250
	18 NEF	41.5 MM	1.6339
1 3/4	5 NC	1 35/64	1.5469
	8 N	1 5/8	1.6250
	12 N	1 43/64	1.6719
	16 NEF	1 11/16	1.6875
1 13/16	16 N	1 3/4	1.7500
1 7/8	8 N	1 3/4	1.7500
	12 N	45.5 MM	1.7913
	16 N	1 13/16	1.8125
1 15/16	16 N	1 7/8	1.8750
2	4 1/2 NC	1 25/32	1.7812
	8 N	1 7/8	1.8750
	12 N	1 59/64	1.9219
	16 NEF	1 15/16	1.9375
2 1/16	16 N	2	2.0000
2 1/8	8 N	2	2.0000
	12 N	2 3/64	2.0469
	16 N	2 1/16	2.0625
2 3/16	16 N	2 1/8	2.1250
2 1/4	4 1/2 NC	2 1/32	2.0312
	8 N	2 1/8	2.1250
	12 N	55 MM	2.1654
	16 N	2 3/16	2.1875
2 5/16	16 N	2 1/4	2.2500
2 3/8	12 N	2 19/64	2.2969
	16 N	2 5/16	2.3125
2 7/16	16 N	2 3/8	2.3750
2 1/2	4 NC	2 1/4	2.2500
	8 N	2 3/8	2.3750
	12 N	61.5 MM	2.4213
	16 N	2 7/16	2.4375
2 5/8	12 N	64.5 MM	2.5394
	16 N	2 9/16	2.5625
2 3/4	4 NC	2 1/2	2.5000
	8 N	2 5/8	2.6250
	12 N	2 43/64	2.6719
	16 N	2 11/16	2.6875
2 7/8	12 N	71 MM	2.7953
	16 N	2 13/16	2.8125
3	4 NC	2 3/4	2.7500
	8 N	2 7/8	2.8750
	12 N	74 MM	2.9134
	16 N	2 15/16	2.9375
3 1/8	12 N	3 1/16	3.0625
	16 N	3 1/16	3.0625
3 1/4	4 NC	3	3.0000
	8 N	3 1/8	3.1250
	12 N	3 3/16	3.1875
	16 N	3 3/16	3.1875
3 3/8	12 N	3 5/16	3.3125
	16 N	3 5/16	3.3125
3 1/2	4 NC	3 1/4	3.2500
	8 N	3 3/8	3.3750
	12 N	3 7/16	3.4375
	16 N	3 7/16	3.4375
3 3/4	4 NC	3 1/2	3.5000

* To produce approximately 75% full thread

Table IV
AMERICAN STANDARD WRENCH HEAD BOLTS AND NUTS - REGULAR SERIES

HEADS - Unfinished, Sq. and Hex.; Semi-fin., Hex. Only						NUTS - Unfinished, Sq. and Hex.; Semi-fin., Hex.Only JAM NUTS - Unfinished and Semi-fin., Hex.Only						
Diam. of Bolt	Width			Height		Width			Thickness-Reg.		Thickness - Jam	
	Across Flats	Across Corners		Unfin. Sq. and Hex.	Semifin. Hex.	Across Flats	Across Corners		Unfin. Sq. and Hex.	Semifin. Hex.	Unfinished	Semi-finished
		Hex.	Square				Hex.	Square				
1/4	3/8	.433	.530	11/64	5/32	7/16	.505	.619	7/32	13/64	5/32	9/64
5/16	1/2	.577	.707	13/64	3/16	9/16	.649	.796	17/64	1/4	3/16	11/64
3/8	9/16	.649	.796	1/4	15/64	5/8	.722	.884	21/64	5/16	7/32	13/64
7/16	5/8	.722	.884	19/64	9/32	3/4	.866	1.061	3/8	23/64	1/4	15/64
1/2	3/4	.866	1.061	21/64	19/64	13/16	.938	1.149	7/16	27/64	5/16	19/64
9/16	7/8	1.010	1.237	3/8	11/32	7/8	1.010	1.237	1/2	31/64	11/32	21/64
5/8	15/16	1.082	1.326	27/64	25/64	1	1.155	1.414	35/64	17/32	3/8	23/64
3/4	1 1/8	1.299	1.591	1/2	15/32	1 1/8	1.299	1.591	21/32	41/64	7/16	27/64
7/8	1 5/16	1.516	1.856	19/32	9/16	1 5/16	1.516	1.856	49/64	3/4	1/2	31/64
1	1 1/2	1.732	2.121	21/32	19/32	1 1/2	1.732	2.121	7/8	55/64	9/16	35/64
1 1/8	1 11/16	1.949	2.387	3/4	11/16	1 11/16	1.949	2.387	1	31/32	5/8	39/64
1 1/4	1 7/8	2.165	2.652	27/32	25/32	1 7/8	2.165	2.651	1 3/32	1 1/16	3/4	23/32
1 3/8	2 1/16	2.381	2.917	29/32	27/32	2 1/16	2.382	2.917	1 13/64	1 11/64	13/16	25/32
1 1/2	2 1/4	2.598	3.182	1	15/16	2 1/4	2.598	3.182	1 5/16	1 9/32	7/8	27/32
1 5/8	2 7/16	2.815	3.447	1 3/32	1 1/32	2 7/16	2.815	3.447	1 27/64	1 25/64	15/16	29/32
1 3/4	2 5/8	3.031	3.712	1 5/32	1 3/32	2 5/8	3.031	3.712	1 17/32	1 1/2	1	31/32
1 7/8	2 13/16	3.248	3.979	1 1/4	1 3/16	2 13/16	3.248	3.979	1 41/64	1 39/64	1 1/16	1 1/32
2	3	3.464	4.243	1 11/32	1 7/32	3	3.464	4.243	1 3/4	1 23/32	1 1/8	1 3/32
2 1/4	3 3/8	3.897	4.773	1 1/2	1 3/8	3 3/8	3.897	4.773	1 31/32	1 59/64	1 1/4	1 13/64
2 1/2	3 3/4	4.330	5.303	1 21/32	1 17/32	3 3/4	4.330	5.303	2 3/16	2 9/64	1 1/2	1 29/64
2 3/4	4 1/8	4.763	5.834	1 13/16	1 11/16	4 1/8	4.763	5.834	2 13/32	2 23/64	1 5/8	1 37/64
3	4 1/2	5.196	6.364	2	1 7/8	4 1/2	5.196	6.364	2 5/8	2 27/64	1 3/4	1 45/64

Finished Regular Bolt Heads and Nuts, When Specified, Are Made to the Dimensions Given For Semi-finished Bolts and Nuts.

Table V

AMERICAN STANDARD WRENCH HEAD BOLTS AND NUTS - HEAVY SERIES

HEADS - Unfinished, Sq. and Hex. Semi-finished, Hex. Only						NUTS - Unfinished, Sq. and Hex., Semi-fin., Hex.Only JAM NUTS - Unfinished and Semi-fin., Hex. Only						
Diam. of Bolt	Width			Height		Width			Thickness-Heavy		Thickness - Jam	
	Across Flats	Across Corners		Unfin. Sq. and Hex.	Semifin. Hex.	Across Flats	Across Corners		Unfin. Sq. and Hex.	Semifin. Hex.	Unfinished	Semi-finished
		Hex.	Square				Hex.	Square				
1/2	7/8	969	1.167	7/16	13/32	7/8	.969	1.167	1/2	31/64	5/16	19/64
9/16	15/16	1.037	1 249	15/32	7/16	15/16	1.037	1.249	9/16	35/64	11/32	21/64
5/8	1 1/16	1.175	1.416	17/32	1/2	1 1/16	1.175	1.416	5/8	39/64	3/8	23/64
3/4	1 1/4	1 383	1.665	5/8	19/32	1 1/4	1.382	1.665	3/4	47/64	7/16	27/64
7/8	1 7/16	1.589	1.914	23/32	11/16	1 7/16	1.589	1.914	7/8	55/64	1/2	31/64
1	1 5/8	1.796	2.162	13/16	3/4	1 5/8	1.796	2.162	1	63/64	9/16	35/64
1 1/8	1 13/16	2.002	2.411	29/32	27/32	1 13/16	2.002	2.411	1 1/8	1 7/64	5/8	39/64
1 1/4	2	2 209	2.661	1	15/16	2	2.209	2.661	1 1/4	1 7/32	3/4	23/32
1 3/8	2 3/16	2.416	2.909	1 3/32	1 1/32	2 3/16	2.416	2.909	1 3/8	1 11/32	13/16	25/32
1 1/2	2 3/8	2.622	3.158	1 3/16	1 1/8	2 3/8	2.622	3.158	1 1/2	1 15/32	7/8	27/32
1 5/8	2 9/16	2.828	3.406	1 9/32	1 7/32	2 9/16	2.828	3.406	1 5/8	1 19/32	15/16	29/32
1 3/4	2 3/4	3.036	3.655	1 3/8	1 5/16	2 3/4	3.035	3.655	1 3/4	1 23/32	1	31/32
1 7/8	2 15/16	3.242	3.905	1 15/32	1 13/32	2 15/16	3.242	3.905	1 7/8	1 27/32	1 1/16	1 1/32
2	3 1/8	3.449	4.153	1 9/16	1 7/16	3 1/8	3.449	4.153	2	1 31/32	1 1/8	1 3/32
2 1/4	3 1/2	3.862	4.652	1 3/4	1 5/8	3 1/2	3.862	4.652	2 1/4	2 13/64	1 1/4	1 13/64
2 1/2	3 7/8	4.275	5.149	1 15/16	1 13/16	3 7/8	4.275	5.149	2 1/2	2 29/64	1 1/2	1 29/64
2 3/4	4 1/4	4.688	5.646	2 1/8	2	4 1/4	4.688	5.646	2 3/4	2 45/64	1 5/8	1 37/64
3	4 5/8	5.102	6.144	2 5/16	2 3/16	4 5/8	5.102	6.144	3	2 61/64	1 3/4	1 45/64

Finished Heavy Bolt Heads and Nuts When Specified Are Made to the Dimensions Given For Semi-finished Bolt Heads and Nuts.

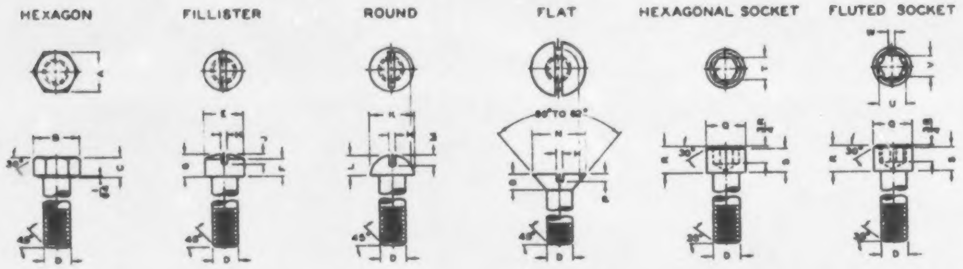
Table VI

RECOMMENDED MINIMUM THREAD LENGTHS FOR BOLTS

Bolt Length	NOMINAL DIAMETER OF BOLT														
	No. 10 1/4	5/16 3/8	7/16 1/2	9/16 5/8	3/4	7/8	1	1 1/8 1 1/4	1 3/8 1 1/2	1 5/8 1 3/4	1 7/8 2	2 1/4	2 1/2	2 3/4	3
	MINIMUM LENGTH OF THREAD														
3/4	1/2	1/2													
1	3/4	3/4	3/4	3/4											
1 1/4	3/4	3/4	1	1	1										
1 1/2	3/4	7/8	1	1 1/8	1 1/8	1 1/8									
1 3/4	3/4	7/8	1	1 3/16	1 3/8	1 3/8	1 3/8								
2	3/4	1	1 1/4	1 1/4	1 3/8	1 9/16	1 5/8	1 5/8							
2 1/2	3/4	1	1 1/4	1 1/2	1 1/2	1 9/16	1 3/4	2	2						
3	7/8	1	1 1/4	1 1/2	1 3/4	1 3/4	1 3/4	2 1/8	2 1/2	2 1/2					
4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/4	2 1/2	2 7/8	3 1/4	3 1/4	3 1/4		
5	7/8	1 3/16	1 1/4	1 1/2	1 3/4	2	2 1/4	2 3/4	2 3/4	2 7/8	3 1/4	3 5/8	4	4 1/8	4 1/4
6	7/8	1 3/16	1 1/2	1 1/2	1 3/4	2	2 1/4	2 3/4	3 1/4	3 1/4	3 1/4	3 5/8	4	4 1/8	4 3/4
8	7/8	1 3/16	1 1/2	1 13/16	2	2	2 1/4	2 3/4	3 1/4	3 3/4	4	4	4	4 1/8	4 3/4
10	7/8	1 3/16	1 1/2	1 13/16	2 1/8	2 7/16	2 1/2	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	4 3/4	4 3/4	4 3/4
12	7/8	1 3/16	1 1/2	1 13/16	2 1/8	2 7/16	2 3/4	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4
16	1	1 3/16	1 1/2	1 13/16	2 1/8	2 7/16	2 3/4	3 1/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4
20	1	1 3/8	1 1/2	1 13/16	2 1/8	2 7/16	2 3/4	3 3/8	4	4 5/8	4 3/4	4 3/4	5 1/4	5 3/4	6 1/4
30			1 3/4	1 13/16	2 1/8	2 7/16	2 3/4	3 3/8	4	4 5/8	5 1/4	5 7/8	6 1/2	6 1/2	6 1/2

Table VII

DIMENSIONS OF CAP SCREW HEADS

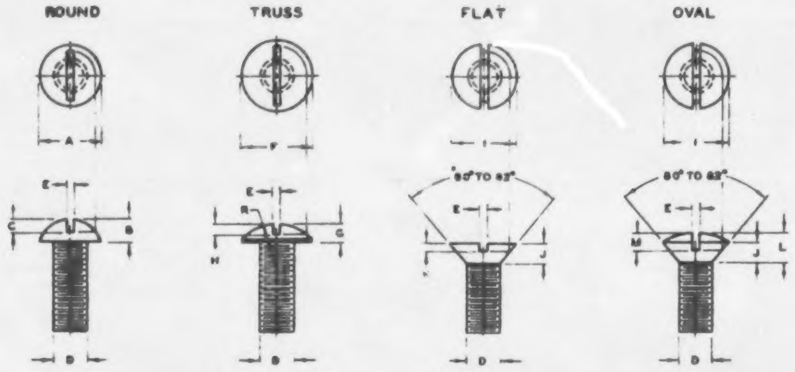


Diam.	A	B	C	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	
2-.086															.140 .136	.086 .083	.070	1/16	.074 .073	.064 .063	.016 .015	Max. Min.
3-.099															.161 .157	.099 .096	.081	5/64	.098 .097	.082 .080	.022 .021	Max. Min.
4-.112															.183 .178	.112 .109	.103	5/64	.098 .097	.082 .080	.022 .021	Max. Min.
5-.125															.205 .200	.125 .122	.115	3/32	.115 .113	.098 .096	.025 .023	Max. Min.
6-.138															.226 .221	.138 .134	.127	3/32	.115 .113	.098 .096	.025 .023	Max. Min.
8-.164															.270 .265	.164 .160	.150	1/8	.149 .147	.128 .126	.032 .030	Max. Min.
10-.190															5/16	.190 .185	.174	5/32	.188 .186	.163 .161	.039 .037	Max. Min.
12-.216															11/32	.216 .211	.198	5/32	.188 .186	.163 .161	.039 .037	Max. Min.
1/4	7/16	.505	3/16	3/8	.172 .157	.218 .196	.075 .064	.097 .077	7/16	.191 .175	.117 .097	1/2	.140	.068 .046	3/8	1/4	.220	3/16	.221 .219	.190 .188	.050 .048	Max. Min.
5/16	1/2	.577	13/64	7/16	.203 .186	.253 .230	.084 .072	.115 .090	9/16	.246 .226	.151 .126	5/8	.176	.086 .057	7/16	5/16	.286	7/32	.256 .254	.221 .219	.060 .058	Max. Min.
3/8	9/16	.649	9/32	9/16	.250 .229	.314 .285	.094 .081	.142 .113	5/8	.273 .252	.168 .138	3/4	.210	.103 .088	9/16	3/8	.344	5/16	.380 .377	.319 .316	.092 .089	Max. Min.
7/16	5/8	.722	21/64	5/8	.297 .274	.368 .337	.094 .081	.168 .133	3/4	.328 .302	.202 .167	13/16	.210	.103 .088	5/8	7/16	.401	5/16	.380 .377	.319 .316	.092 .089	Max. Min.
1/2	3/4	.866	3/8	3/4	.328 .301	.412 .376	.106 .091	.188 .148	13/16	.355 .328	.219 .179	7/8	.210	.103 .088	3/4	1/2	.458	3/8	.463 .460	.386 .383	.112 .109	Max. Min.
9/16	13/16	.938	27/64	13/16	.375 .347	.466 .428	.118 .102	.214 .169	15/16	.410 .379	.253 .206	1	.245	.120 .090	13/16	9/16	.516	3/8	.463 .460	.386 .383	.112 .109	Max. Min.
5/8	7/8	1.010	15/32	7/8	.422 .392	.521 .480	.133 .116	.240 .190	1	.438 .406	.270 .220	1 1/8	.281	.137 .083	7/8	5/8	.573	1/2	.604 .601	.509 .506	.138 .134	Max. Min.
3/4	1	1.155	9/16	1	.500 .468	.612 .566	.149 .131	.283 .233	1 1/4	.547 .506	.337 .277	1 3/8	.352	.171 .115	1	3/4	.688	9/16	.631 .627	.535 .531	.149 .145	Max. Min.
7/8	1 1/8	1.299	21/32	1 1/8	.594 .556	.720 .669	.167 .147	.334 .264				1 5/8	.423	.206 .130	1 1/8	7/8	.803	9/16	.709 .705	.604 .600	.168 .164	Max. Min.
1	1 5/16	1.516	3/4	1 5/16	.656 .613	.803 .744	.188 .166	.372 .293				1 7/8	.494	.240 .163	1 5/16	1	.917	5/8	.801 .797	.685 .681	.190 .186	Max. Min.
1 1/8	1 1/2	1.732	27/32												1 1/2	1 1/8	1.031	3/4	.970 .966	.828 .824	.231 .227	Max. Min.
1 1/4	1 11/16	1.949	15/16												1 3/4	1 1/4	1.146	3/4	.970 .966	.828 .824	.231 .227	Max. Min.
1 3/8															1 7/8	1 3/8	1.260	3/4	.970 .966	.828 .824	.231 .227	Max. Min.
1 1/2															2	1 1/2	1.375	1	1.275 1.271	1.007 1.003	.298 .294	Max. Min.

Length of Thread on Hexagon, Fillister, Round and Flat = 2 D + 1/4"

Length of Thread on Hex. and Fluted Socket, For NC Thread = 2D + 1/2", or 1/2 Bolt Length } Whichever is Greater
For NF Thread = 1 1/2D + 1/2, or 3/8 Bolt Length

TABLE VIII - DIMENSIONS OF MACHINE SCREW HEADS

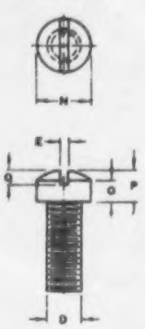


Diam.	A	B	C	E	F	G	H	H¹	I	J	K	L	M	N	
0-.060	.113 .099	.053 .043	.039 .029	.023 .016					.119 .105	.035 .026	.015 .010	.056 .041	.030 .025	.096 .083	Max. Min.
1-.073	.138 .122	.061 .051	.044 .033	.026 .019					.146 .130	.043 .033	.019 .012	.068 .052	.038 .031	.118 .104	Max. Min.
2-.086	.162 .146	.069 .059	.048 .037	.031 .023	.194 .180	.053 .044	.031 .022	.050 .040	.172 .156	.051 .040	.023 .015	.080 .063	.045 .037	.140 .124	Max. Min.
3-.099	.187 .169	.078 .067	.053 .040	.035 .027	.226 .211	.061 .051	.036 .026	.056 .044	.199 .181	.059 .048	.027 .017	.093 .073	.052 .043	.161 .145	Max. Min.
4-.112	.211 .193	.086 .075	.058 .044	.039 .031	.257 .241	.069 .059	.040 .030	.060 .048	.225 .207	.067 .055	.030 .020	.104 .084	.059 .049	.183 .166	Max. Min.
5-.125	.236 .217	.095 .083	.063 .047	.043 .035	.289 .272	.078 .066	.045 .034	.070 .058	.252 .232	.075 .062	.034 .022	.116 .095	.067 .055	.205 .187	Max. Min.
6-.138	.260 .240	.103 .091	.068 .051	.048 .039	.321 .303	.086 .074	.050 .037	.080 .067	.279 .257	.083 .069	.038 .024	.128 .105	.074 .060	.226 .208	Max. Min.
8-.164	.309 .287	.120 .107	.077 .058	.054 .045	.384 .364	.102 .088	.058 .045	.110 .096	.332 .308	.100 .084	.045 .029	.152 .126	.088 .072	.270 .250	Max. Min.
10-.190	.359 .334	.137 .123	.087 .065	.060 .050	.448 .425	.118 .103	.068 .053	.120 05	.385 .359	.116 .096	.053 .034	.176 .148	.103 .084	.313 .292	Max. Min.
12-.216	.408 .382	.153 .139	.096 .072	.067 .056	.511 .487	.134 .118	.077 .061	.155 .139	.438 .410	.132 .112	.060 .039	.200 .169	.117 .096	.357 .334	Max. Min.
1/4	.472 .443	.175 .160	.109 .082	.075 .064	.573 .546	.150 .133	.087 .070	.190 .172	.507 .477	.153 .131	.070 .046	.232 .197	.136 .112	.414 .389	Max. Min.
5/16	.590 .557	.216 .198	.132 .099	.084 .072	.698 .666	.183 .162	.106 .085	.230 .208	.635 .600	.191 .165	.088 .058	.290 .249	.171 .141	.518 .490	Max. Min.
3/8	.706 .670	.256 .237	.155 .117	.094 .081	.823 .787	.215 .191	.124 .100	.295 .270	.782 .722	.230 .200	.106 .070	.347 .300	.206 .170	.622 .590	Max. Min.
7/16	.750 .707	.328 .307	.196 .148	.094 .081	.948 .907	.248 .221	.142 .116		.812 .771	.223 .180	.103 .066	.345 .295	.210 .174	.635 .589	Max. Min.
1/2	.813 .756	.355 .332	.211 .159	.106 .091	1.073 1.026	.280 .250	.161 .131		.875 .831	.223 .186	.103 .065	.354 .299	.216 .176	.750 .710	Max. Min.
9/16	.938 .887	.410 .385	.242 .185	.118 .102	1.198 1.149	.312 .279	.179 .146		1.000 .950	.260 .220	.120 .077	.410 .350	.250 .207	.812 .768	Max. Min.
5/8	1.000 .944	.438 .411	.258 .195	.133 .116	1.323 1.269	.345 .309	.196 .162		1.125 1.069	.298 .253	.137 .088	.467 .399	.285 .235	.875 .827	Max. Min.
3/4	1.250 1.185	.547 .516	.320 .242	.149 .131	1.573 1.511	.410 .368	.234 .182		1.375 1.306	.372 .319	.171 .111	.578 .497	.353 .293	1.000 .945	Max. Min.

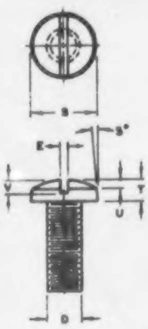
* Flat Head Machine Screws Also Are Made With 100° Angle

TABLE VIII - DIMENSIONS OF MACHINE SCREW HEADS

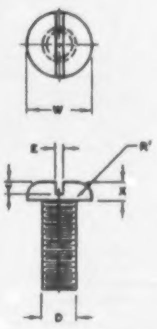
FILLISTER



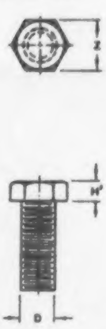
BINDING



PAN



HEXAGON

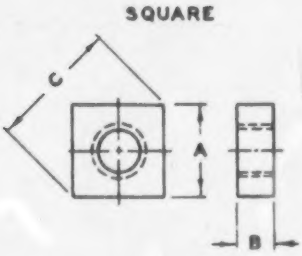


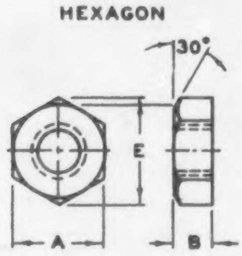
Diam.	O	P	Q	R	R^1	S	T	U	V	W	X	Y	Z	
0-.060	.045 .037	.059 .043	.025 .015											Max. Min.
1-.073	.053 .045	.071 .055	.031 .020											Max. Min.
2-.086	.062 .053	.083 .066	.037 .025	.129	.035	.181 .171	.046 .041	.018 .013	.030 .024	.167 .155	.053 .045	.033 .023	.125 .120	Max. Min.
3-.099	.070 .061	.095 .077	.043 .030	.151	.037	.208 .197	.054 .048	.022 .016	.036 .029	.193 .180	.060 .051	.037 .027	.187 .181	Max. Min.
4-.112	.079 .069	.107 .088	.048 .035	.169	.042	.235 .223	.063 .056	.025 .018	.042 .034	.219 .205	.068 .058	.041 .030	.187 .181	Max. Min.
5-.125	.088 .078	.120 .100	.054 .040	.191	.044	.263 .249	.071 .064	.029 .021	.048 .039	.245 .231	.075 .065	.045 .032	.187 .181	Max. Min.
6-.138	.096 .086	.132 .111	.060 .045	.211	.046	.290 .275	.080 .071	.032 .024	.053 .044	.270 .256	.082 .072	.050 .038	.250 .244	Max. Min.
8-.164	.113 .102	.156 .133	.071 .054	.254	.052	.344 .326	.097 .087	.039 .029	.065 .054	.322 .306	.096 .085	.058 .043	.250 .244	Max. Min.
10-.190	.130 .118	.180 .156	.083 .064	.283	.061	.399 .378	.114 .102	.045 .034	.077 .064	.373 .357	.110 .099	.067 .050	.312 .305	Max. Min.
12-.216	.148 .134	.205 .178	.094 .074	.336	.078	.454 .430	.130 .117	.052 .039	.089 .074	.425 .407	.125 .112	.077 .060	.312 .305	Max. Min.
1/4	.170 .155	.237 .207	.109 .087	.375	.087	.513 .488	.153 .138	.061 .046	.105 .088	.492 .473	.144 .130	.087 .070	.375 .367	Max. Min.
5/16	.211 .194	.295 .262	.137 .110	.457	.099	.641 .609	.193 .174	.077 .059	.134 .112	.615 .594	.178 .162	.109 .092	.500 .491	Max. Min.
3/8	.253 .233	.355 .315	.164 .133	.538	.143	.769 .731	.234 .211	.094 .071	.163 .136	.740 .716	.212 .195	.130 .113	.562 .552	Max. Min.
7/16	.265 .242	.368 .321	.170 .135	.619										Max. Min.
1/2	.297 .273	.412 .362	.190 .151	.701										Max. Min.
9/16	.336 .308	.466 .410	.214 .172	.783										Max. Min.
5/8	.375 .345	.521 .461	.240 .193	.863										Max. Min.
3/4	.441 .406	.612 .542	.281 .220	1.024										Max. Min.

Length of Thread: Screws 2" or Shorter are Threaded to Head. Screws over 2" are Threaded 1 3/4" Minimum. Screw Heads Also are Made With Cross Recess Slots.

Table IX

DIMENSIONS OF MACHINE SCREW AND STOVE BOLT NUTS

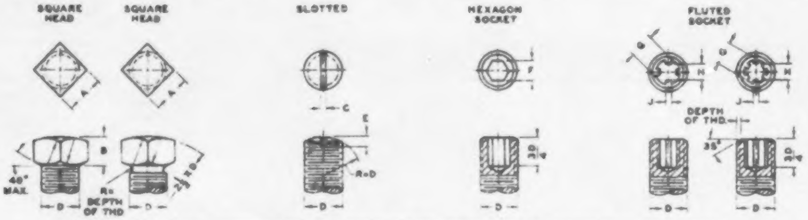




Diameter of Thread	A			B			C	E
		Max.	Min.		Max.	Min.		
0-.060	5/32	.1562	.150	3/64	.050	.043	.2209	.1804
1-.073	5/32	.1562	.150	3/64	.050	.043	.2209	.1804
2-.086	3/16	.1875	.180	1/16	.066	.057	.2651	.2165
3-.099	3/16	.1875	.180	1/16	.066	.057	.2651	.2165
4-.112	1/4	.250	.241	3/32	.098	.087	.3535	.2886
5-.125	5/16	.3125	.302	7/64	.114	.102	.4419	.3608
6-.138	5/16	.3125	.302	7/64	.114	.102	.4419	.3608
8-.164	11/32	.3438	.332	1/8	.130	.117	.4861	.3968
10-.190	3/8	.375	.362	1/8	.130	.117	.5303	.4329
12-.216	7/16	.4375	.423	5/32	.161	.148	.6187	.5051
1/4	7/16	.4375	.423	3/16	.193	.178	.6187	.5051
5/16	9/16	.5625	.545	7/32	.225	.208	.7955	.6494
3/8	5/8	.625	.607	1/4	.257	.239	.8839	.7216

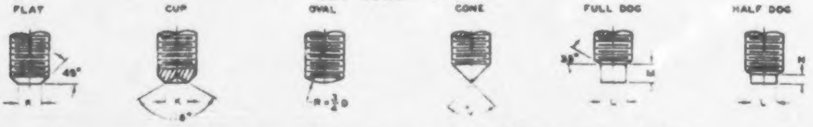
Table X

DIMENSIONS OF SQUARE HEAD AND HEADLESS SET SCREWS


SQUARE HEAD
SQUARE HEAD
SLOTTED
HEXAGON SOCKET
FLUTED SOCKET
A
B
C
E
F
G
H
J
40° MAX
R = DEPTH OF THD
2 1/2 R D
R=D
DEPTH OF THD.
35°
D

Diam.	A	B	C	E	F	G	H	J	K	L	M	N	
5-.125			.023	.031	1/16	.071 .070	.053 .052	.022 .021	1/16	.083 .078	.06	.03	Max. Min.
6-.138			.025	.035	1/16	.079 .078	.056 .055	.022 .021	.069	.092 .087	.07	.03	Max. Min.
8-.164			.029	.041	5/64	.098 .097	.082 .080	.022 .021	5/64	.109 .103	.08	.04	Max. Min.
10-.190			.032	.048	3/32	.115 .113	.098 .096	.025 .023	3/32	.127 .120	.09	.04	Max. Min.
12-.216			.036	.054	3/32	.115 .113	.098 .096	.025 .023	7/64	.144 .137	.11	.06	Max. Min.
1/4	1/4	3/16	.045	.063	1/8	.149 .147	.128 .126	.032 .030	1/8	5/32	1/8	1/16	Max. Min.
5/16	5/16	15/64	.051	.078	5/32	.188 .186	.163 .161	.039 .037	11/64	13/64	5/32	5/64	Max. Min.
3/8	3/8	9/32	.064	.094	3/16	.221 .219	.190 .188	.050 .048	13/64	1/4	3/16	3/32	Max. Min.
7/16	7/16	21/64	.072	.109	7/32	.256 .254	.221 .219	.060 .058	15/64	19/64	7/32	7/64	Max. Min.
1/2	1/2	3/8	.081	.125	1/4	.298 .296	.254 .252	.068 .066	9/32	11/32	1/4	1/8	Max. Min.
9/16	9/16	27/64	.091	.141	1/4	.298 .296	.254 .252	.068 .066	5/16	25/64	9/32	9/64	Max. Min.
5/8	5/8	15/32	.102	.156	5/16	.380 .377	.319 .316	.092 .089	23/64	15/32	5/16	5/32	Max. Min.
3/4	3/4	9/16	.129	.188	3/8	.463 .460	.386 .383	.112 .109	7/16	9/16	3/8	3/16	Max. Min.
7/8	7/8	21/32			1/2	.604 .601	.509 .506	.138 .134	33/64	21/32	7/16	7/32	Max. Min.
1	1	3/4			9/16	.631 .627	.535 .531	.149 .145	19/32	3/4	1/2	1/4	Max. Min.
1 1/8	1 1/8	27/32			9/16	.709 .705	.604 .600	.168 .164	43/64	27/32	9/16	9/32	Max. Min.
1 1/4	1 1/4	15/16			5/8	.801 .797	.685 .681	.189 .185	3/4	15/16	5/8	5/16	Max. Min.
1 3/8	1 3/8	1 1/32			5/8	.869 .865	.744 .740	.207 .203	53/64	1 1/32	11/16	11/32	Max. Min.
1 1/2	1 1/2	1 1/8			3/4	.970 .966	.828 .824	.231 .227	29/32	1 1/8	3/4	3/8	Max. Min.
1 3/4					1	1.275 1.271	1.007 1.003	.298 .294	1 1/16	1 5/16	7/8	7/16	Max. Min.
2					1	1.275 1.271	1.007 1.003	.298 .294	1 7/32	1 1/2	1	1/2	Max. Min.

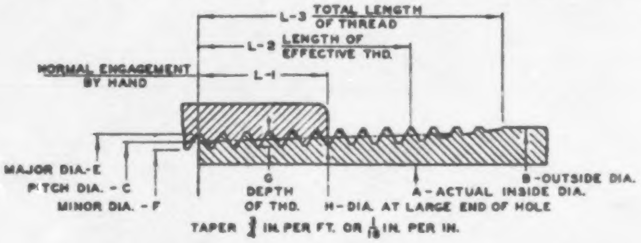
SET SCREW POINTS


FLAT
CUP
OVAL
CONE
FULL DOG
HALF DOG
45°
R
K
Y°
R = 3/4 D
Y
35°
M
N
L

*Angle $Y = 118^\circ$ When Length Equals Diam. or Less. $Y = 90^\circ$ When Length Exceeds Diam

Table XI

DIMENSIONS OF AMERICAN NATIONAL TAPER PIPE THREADS


L-3 TOTAL LENGTH OF THREAD
L-2 LENGTH OF EFFECTIVE THD.
NORMAL ENGAGEMENT BY HAND
L-1
MAJOR DIA.-E
PITCH DIA. - C
MINOR DIA. - F
G DEPTH OF THD.
H-DIA. AT LARGE END OF HOLE
A-ACTUAL INSIDE DIA.
B-OUTSIDE DIA.
TAPER 3/4 IN. PER FT. OR 1/16 IN. PER IN.

Nominal Pipe Size	Thds per In	A	B	C	E	F	G	L-1	L-2	L-3	H Reamer Dia.	Tap Drill Size
1/16	27	.181	.3125	.271	.301	.242	.0296	.160	.261	.390	.252	1/4
1/8	27	.269	.405	.364	.393	.334	.0296	.180	.264	.392	.345	11/32
1/4	18	.364	.540	.477	.522	.433	.0444	.200	.402	.595	.445	7/16
3/8	18	.493	.675	.612	.656	.568	.0444	.240	.408	.601	.583	19/32
1/2	14	.622	.840	.758	.816	.701	.0571	.320	.534	.782	.721	23/32
3/4	14	.824	1.050	.968	1.025	.911	.0571	.339	.546	.794	.932	15/16
1	11 1/2	1.049	1.315	1.214	1.283	1.144	.0696	.400	.683	.985	1.169	1 5/32
1 1/4	11 1/2	1.380	1.660	1.557	1.627	1.488	.0696	.420	.707	1.009	1.514	1 1/2
1 1/2	11 1/2	1.610	1.900	1.796	1.866	1.727	.0696	.420	.724	1.025	1.753	1 23/32
2	11 1/2	2.067	2.375	2.269	2.339	2.200	.0696	.436	.757	1.058	2.227	2 3/16
2 1/2	8	2.469	2.875	2.720	2.820	2.620	.100	.682	1.138	1.571	2.662	2 5/8
3	8	3.068	3.500	3.341	3.441	3.241	.100	.766	1.200	1.634	3.289	3 1/4
3 1/2	8	3.548	4.000	3.838	3.938	3.738	.100	.821	1.250	1.684	3.789	3 3/4
4	8	4.026	4.500	4.334	4.434	4.234	.100	.844	1.300	1.734	4.287	4 1/4
5	8	5.047	5.563	5.391	5.491	5.291	.100	.937	1.406	1.841	5.349	5 5/16
6	8	6.065	6.625	6.446	6.546	6.346	.100	.958	1.513	1.947	6.406	6 3/8
8	8	7.981	8.625	8.434	8.534	8.334	.100	1.063	1.713	2.147	8.400	
10	8	10.020	10.750	10.545	10.645	10.445	.100	1.210	1.925	2.359	10.521	
12	8	12.000	12.750	12.533	12.633	12.433	.100	1.360	2.125	2.559	12.518	

TABLE XII STANDARD TABLES OF ENGLISH MEASURE

Linear Measure		
12 inches (in.)	=	1 foot (ft).
3 ft.	=	1 yard (yd.)
16 1/2 ft.	=	1 rod (rd.)
5 1/2 yd.	=	1 rd.
320 rd.	=	1 mile
1760 yd.	=	1 mile
5280 ft.	=	1 mile

Surface Measure		
144 sq. in.	=	1 sq. ft.
9 sq. ft.	=	1 sq. yd.
30 1/4 sq. yd.	=	1 sq. rd.
160 sq. rd.	=	1 acre
640 acres	=	1 sq. mile
43,560 sq. ft.	=	1 acre

Cubic Measure		
1728 cu. in.	=	1 cu. ft.
27 cu. ft.	=	1 cu. yd.
128 cu. ft.	=	1 cord

Angular (Circular) Measure		
60 sec. ('')	=	1 min. (')
60'	=	1 degree (°)
90°	=	1 quadrant
360°	=	1 circle

Time Measure		
60 seconds (sec.)	=	1 minute (min.)
60 min.	=	1 hour (hr.)
24 hr.	=	1 day
7 days	=	1 week
52 weeks	=	1 year
365 days	=	1 year
10 years	=	1 decade

Liquid Measure		
4 gills	=	1 pint (pt.)
2 pt.	=	1 quart (qt.)
4 qt.	=	1 gallon (gal.)
231 cu. in.	=	1 gal.
31.5 gal.	=	1 barrel (bbl.)
42 gal.	=	1 bbl. of oil
8 1/2 lb.	=	1 gal. water
7 1/2 gal.	=	1 cu. ft.

Weights of Materials		
0.096 lb.	=	1 cu. in. aluminum
0.260 lb.	=	1 cu. in. cast iron
0.283 lb.	=	1 cu. in. mild steel
0.321 lb.	=	1 cu. in. copper
0.41 lb.	=	1 cu. in. lead
112 lb.	=	1 cu. ft. Dowmetal
167 lb.	=	1 cu. ft. aluminum
464 lb.	=	1 cu. ft. cast iron
490 lb.	=	1 cu. ft. mild steel
555.6 lb.	=	1 cu. ft. copper
710 lb.	=	1 cu. ft. lead

Avoirdupois Weight		
16 ounces (oz.)	=	1 pound (lb.)
100 lb.	=	1 hundredweight (cwt.)
20 cwt.	=	1 ton
2000 lb.	=	1 ton
8 1/2 lb.	=	1 gal. of water
62.4 lb.	=	1 cu. ft. of water
112 lb.	=	1 long cwt.
2240 lb.	=	1 long ton

Dry Measure		
2 cups	=	1 pt.
2 pt.	=	1 qt.
4 qt.	=	1 gal.
8 qt.	=	1 peck (pk.)
4 pk.	=	1 bushel (bu.)

Miscellaneous		
12 units	=	1 dozen (doz.)
12 doz.	=	1 gross
144 units	=	1 gross
24 sheets	=	1 quire
20 quires	=	1 ream
20 units	=	1 score
6 ft.	=	1 fathom

TABLE XIII STANDARD TABLES OF METRIC MEASURE

Linear Measure

Unit	Value in Meters	Symbol or Abbreviation
Micron	0.000001	μ
Millimeter	0.001	mm.
Centimeter	0.01	cm.
Decimeter	0.1	dm.
Meter (unit)	1.0	m.
Dekameter	10.0	dkm.
Hectometer	100.0	hm.
Kilometer	1,000.00	km.
Myriameter	10,000.0	Mm.
Megameter	1,000,000.0	

Surface Measure

Unit	Value in Square Meters	Symbol or Abbreviation
Square millimeter	0.000001	mm.^{2}
Square centimeter	0.0001	cm.^{2}
Square decimeter	0.01	dm.^{2}
Square meter (centiare)	1.0	m.^{2}
Square dekameter (are)	100.0	a.^{2}
Hectare	10,000.0	ha.^{2}
Square kilometer	1,000,000.0	km.^{2}

Volume

Unit	Value in Liters	Symbol or Abbreviation
Milliliter	0.001	ml.
Centiliter	0.01	cl.
Deciliter	0.1	dl.
Liter (unit)	1.0	l.
Dekaliter	10.0	dkl.
Hectoliter	100.0	hl.
Kiloliter	1,000.0	kl.

Mass

Unit	Value in Grams	Symbol or Abbreviation
Microgram	0.000001	μg.
Milligram	0.001	mg.
Centigram	0.01	cg.
Decigram	0.1	dg.
Gram (unit)	1.0	g.
Dekagram	10.0	dkg.
Hectogram	100.0	hg.
Kilogram	1,000.0	kg.
Myriagram	10,000.0	Mg.
Quintal	100,000.0	q.
Ton	1,000,000.0	

Cubic Measure

Unit	Value in Cubic Meters	Symbol or Abbreviation
Cubic micron	10^{-18}	μ^3
Cubic millimeter	10^{-9}	mm.^{3}
Cubic centimeter	10^{-6}	cm.^{3}
Cubic decimeter	10^{-3}	dm.^{3}
Cubic meter	1	m.
Cubic dekameter	10^3	dkm.^{3}
Cubic hectometer	10^6	hm.^{3}
Cubic kilometer	10^9	km.^{3}